I200

Dual Current Integrator
with Servo Control Option

User Manual

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3 Safety Information

This unit is designed for compliance with harmonized electrical safety standard EN61010-1:2000. It must be used in accordance with its specifications and operating instructions. Operators of the unit are expected to be qualified personnel who are aware of electrical safety issues. The customer's Responsible Body, as defined in the standard, must ensure that operators are provided with the appropriate equipment and training.

The unit is designed to make measurements in **Measurement Category I** as defined in the standard.

CAUTION. The I200 can generate high voltages as follows:

+ or – 1000 V DC at 1mA maximum.

Present on the central conductor of the SHV connector.

These voltages and currents are not classified as hazardous live under EN61010 but may nevertheless give a noticeable shock. The user must therefore exercise appropriate caution when using the device and when connecting cables. Power should be turned off before making any connections.

In applications where high energy charged particle beams can strike electrodes which are normally connected to the I200, voltages limited only by electrical breakdown can build up if the I200 is not connected to provide the earth return path. The user must ensure that a suitable earth return path is always present when the particle beam may be present.

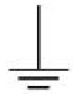
The unit must not be operated unless correctly assembled in its case. Protection from high voltages generated by the device will be impaired if the unit is operated without its case. Only Service Personnel, as defined in EN61010-1, should attempt to work on the disassembled unit, and then only under specific instruction from Pyramid Technical Consultants.

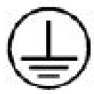
The unit is designed to operate from +24VDC power, with a maximum current requirement of 500mA. A suitably rated power supply module is available as an option. Users who make their own power provision should ensure that the supply cannot source more than 1000mA.

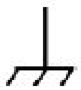
A safety ground must be securely connected to the ground lug on the case.

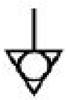
Some of the following symbols may be displayed on the unit, and have the indicated meanings.


Direct current

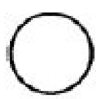

Earth (ground) terminal


Protective conductor terminal


Frame or chassis terminal


Equipotentiality

Supply ON


Supply OFF


CAUTION – RISK OF ELECTRIC SHOCK


CAUTION – RISK OF DANGER – REFER TO MANUAL

4 Models

I200	Two channel gated integrator electrometer with 10pF and 1000pF feedback capacitors.
-XP10/5/2	Add positive 0 to 1000 V / 500 V / 200 V auxiliary bias output
-XN10/5/2	Add negative 0 to 1000V /500 V / 200 V auxiliary bias output
-C/x/y	Change feedback capacitors to x pF and y pF (default is -C10/1000). Options for x are = 10, 30, 60,100; y values from 100 to 3300
-100AB	Add 100x unequal conversion gains option for the input channels
-S1	Add multi-mode servo option
-TRIAX	Signal inputs on 3-lug triax connectors (default is BNC)

Example:

I200-XP10-S1-100AB I200 with standard BNC signal connectors, with options
1000V positive auxiliary bias output,
selectable 100x gain difference on the
multimode servo option.

5 Scope of Supply

I200 model as specified in your order.

Plug pack 24 VDC power supply PSU24-45-1

Serial cable adaptor AB450K-R

USB memory stick containing:
- User manual
- PSI Diagnostic software guide
- PSI diagnostic software files
- USB drivers and utilities

Optional items as specified in your order.

6 Optional Items

6.1 Power supplies

PSU24-45-1. +24 VDC 1.88 A PSU (100-250 VAC, 50-60 Hz, IEC C14 3-pin plug receptacle) with output lead terminated in 2.1mm threaded jack.

PSU24-36-1. +24 VDC 1.5 A PSU (100-250 VAC, 50-60 Hz, IEC C8 2-pin plug receptacle) with output lead terminated in 2.1mm threaded jack.

6.2 Signal cables and cable accessories

CAB-BNC-colo-Cable, coaxial low noise BNC plug to BNC plug, 3-lug, 3 m.

CAB-SHV-CO-3-SHV: Cable, coaxial, SHV to SHV, 3m.

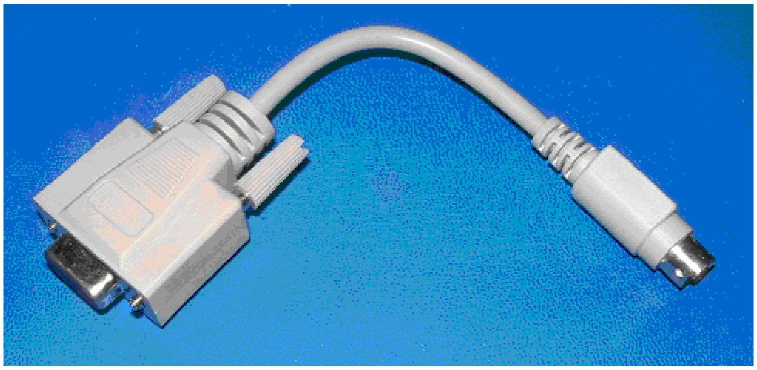
ADBJ77-E2-PL20 Adaptor, triax 3-lug jack to BNC plug. Guard not connected through.

ADBJ20-E2-PL75 Adaptor, BNC jack to triax 3-lug plug. Guard not connected through.

RF175-1 Dust cap, 3-lug triax
SHV to SHV cable, 3m.

6.3 Data cables

AB450K-R RS-232 6 pin DIN male to 9 pin D sub female adaptor.



CAB-ST-P-5-ST (qty two) Fiber-optic cable pair, 5m plastic.

CAB-ST-HCS-5-ST (qty two) Fiber optic cable pair, 5m silica

6.4 Fiber-optic loop

A200 USB to fiber-optic adaptor.

A300 fiber-optic loop controller / Ethernet adaptor.

A500 intelligent cell controller with Ethernet interface.

7 Intended Use and Key Features

7.1 Intended Use

The I200 is intended for the measurement of small charges or corresponding currents (from pA to µA) generated by devices such as ionization chambers, in-vacuum beam position monitors, proportional chambers and photodiodes. Two input channels make the I200 particularly well-suited to split electrode systems used for beam centering.

The -S1 option allows the I200 to function as a PID controller, for applications where an analog voltage is used to control a process and the process variable is a function of the measured input currents. In particular, it is intended to control the crystal cages of double-crystal monochromators used in synchrotron light source beamlines.

The I200 has design features which make it tolerant of electrically noisy environments, but the place of use is otherwise assumed to be clean and sheltered, for example a laboratory or light industrial environment. The unit may be used stand-alone, or networked with other devices and integrated into a larger system. Users are assumed to be experienced in the general use of precision electronic circuits for sensitive measurements, and to be aware of the dangers that can arise in high-voltage circuits.

7.2 Key Features

Highly sensitive charge and current measuring system.

Two parallel gated integrator channels.

External gate input.

Multiple data acquisition modes
- continuous current measurement
- continuous charge integration
- no lost charge integration
- externally-triggered

Dynamic range 0.1pA to 100uA with standard capacitors.

Built-in calibration check current sources feeding each channel.

RS-232, USB and fast fiber-optic serial interfaces built-in. Selectable baud rates.

Can be operated in a fiber-optic serial communication loop with up to thirteen other devices.

100BaseT Ethernet available through the A300 and A500 interfaces.

ASCII and binary serial data formats.

Auxiliary HV output option up to + or – 1000 VDC.

Servo control option. Process parameter can be various arithmetic combinations of the measured currents, controlled parameter is a precision 0 to 10V 16-bit DAC output.

8 Specification

Inputs	Two, independent
Integration time	Adjustable, 20 µs minimum, 65 s maximum.
Input noise current	< 100 fA rms + 1 fA rms per pF input load (0.1 second integration, 10 pF capacitor, 0 V bias)
Input background current	< 100 fA at 0 V bias, 25 C for 8 hours after nulling < 300 fA at 0 V bias, 35 C after for 8 hours after nulling (excluding external background current sources)
Stability	Output drift < 5 ppm / C / hour
Digitization	16 bit over +/- 10 V integrator output range. Multiple conversions per integration possible (sub-sampling) The two channels are connected to the ADC through a multiplexer.
Linearity	Deviation from best fit line of individual readings < 0.1% of maximum current or charge reading for given feedback capacitor and integration time setting.
Drift	< 0.5% over 12 hours.
External accuracy	0.25% of full scale charge / current for the selected capacitor and integration time.
Auxiliary HV PSU (option)	0 to 1000 V programmable 10 bit resolution, 1mA max. Noise and ripple <0.1% of full scale.
External gate (optical)	Phototransistor (HFBR 1528) suitable for 650 nm
External gate (BNC)	0 / +5 V (TTL level), 2 kohm input impedance.
Measurement start modes	Internal ExternalStart: start signal on gate input ExternalStartStop: start and stop on gate input ExternalStartHold: gate input controls integrators directly
Communications	Fiber optic (10 Mbit/sec) USB (3 Mbit/sec) RS-232 (115 kbit/sec)
Power input	+24 VDC (+/-2 V), 350 mA.

Case	Stainless steel.
Case protection rating	The case is designed to rating IP43 (protected against solid objects greater than 1mm in size, protected against spraying water).
Weight	1.64 kg (3.6 lb).
Operating environment	0 to 35 C (15 to 25 C recommended to reduce drift and offset) < 70% humidity, non-condensing vibration < 0.1g all axes (1 to 1000Hz)
Shipping and storage environment	-10 to 50C < 80% humidity, non-condensing vibration < 2 g all axes, 1 to 1000 Hz
Dimensions	(see figures 1 and 2).

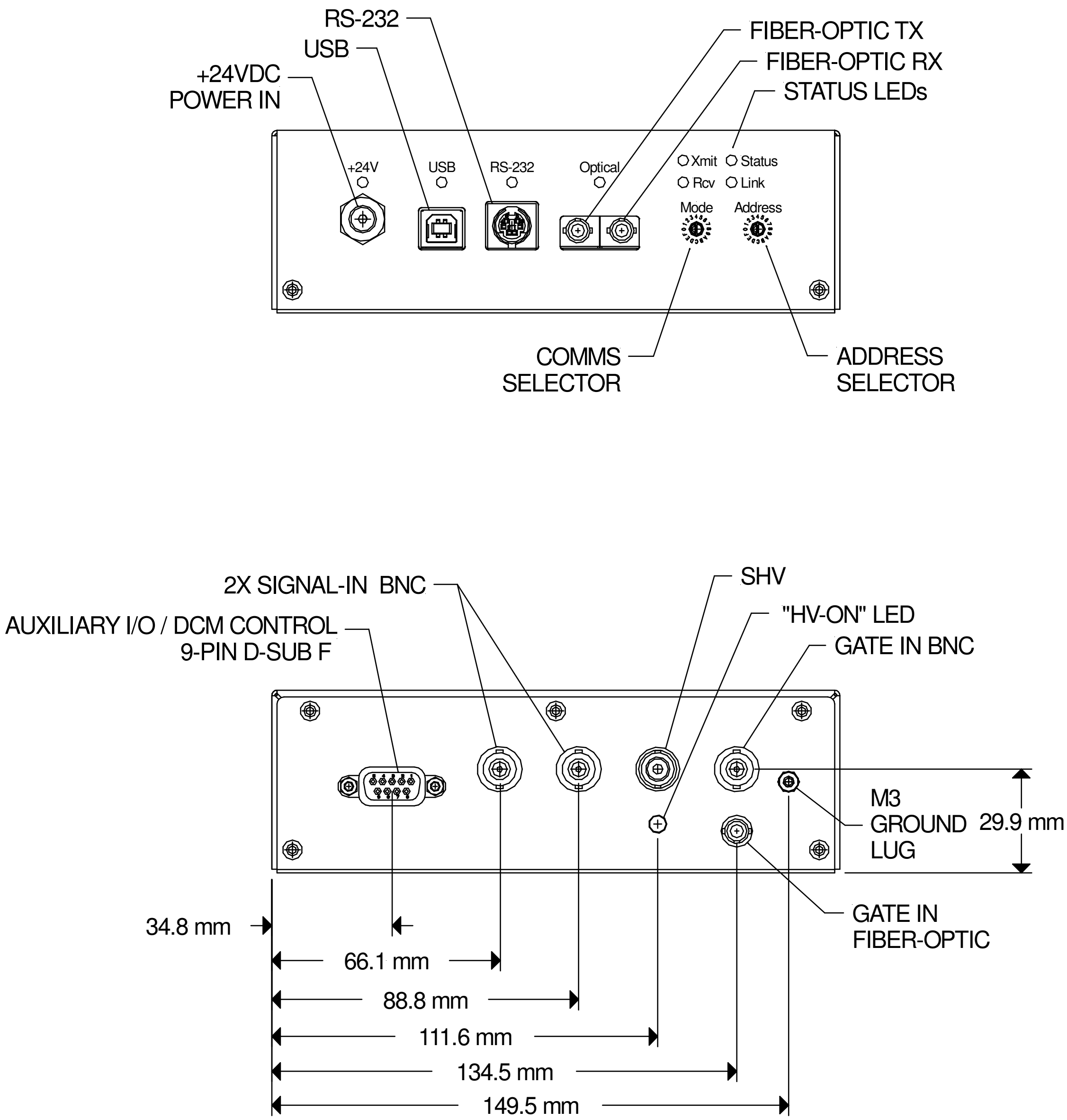


Figure 1. I200 chassis end panels. Dimensions mm.

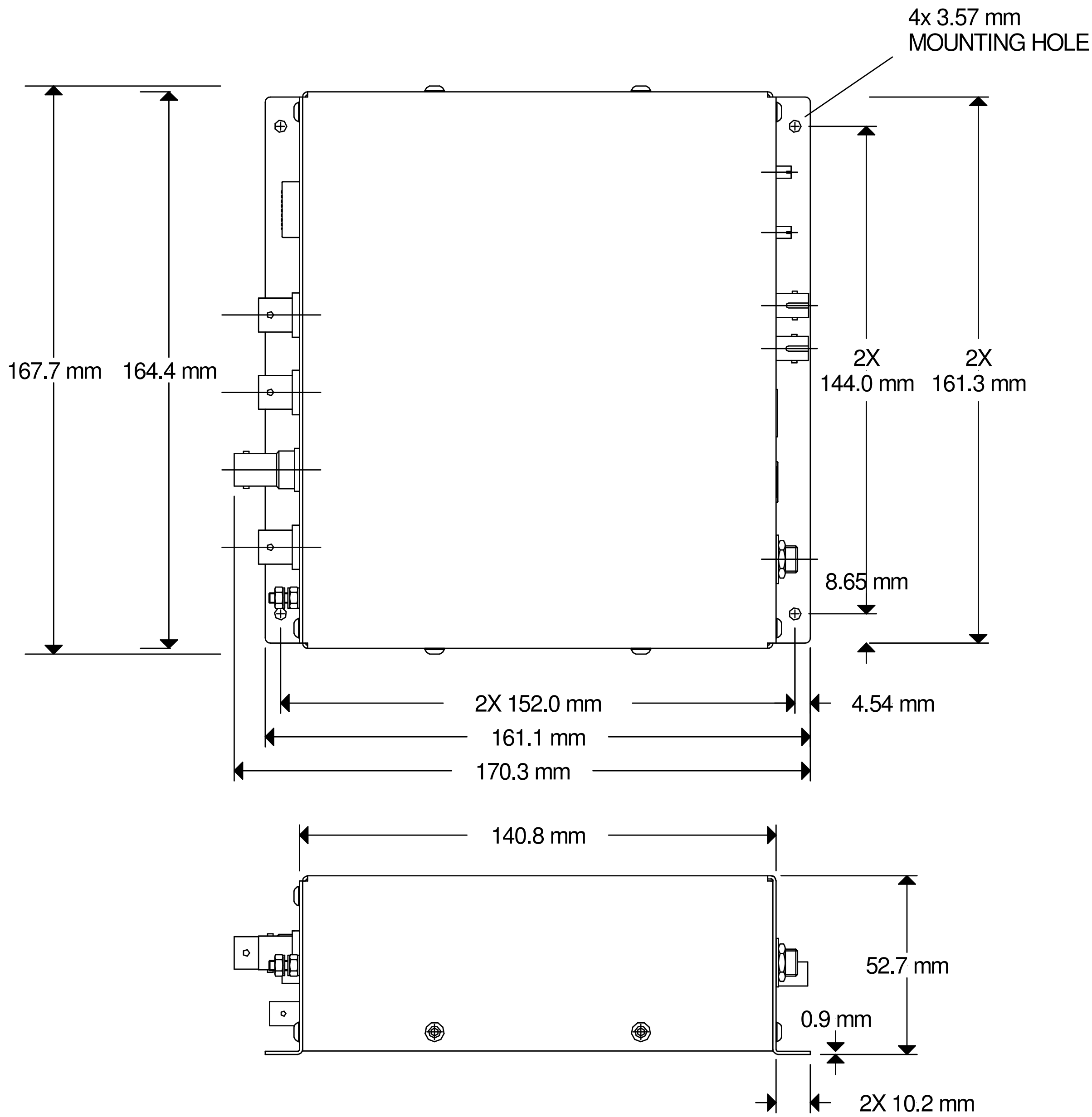


Figure 2. I200 case side and plan views (above). Dimensions mm.

9 How the I200 Works - an Overview

The I200 is a very flexible instrument which uses a charge measurement method that may be unfamiliar to you. This section gives you an overview of how incoming signal current is turned into readings, and the main features of the device. Full details are in the later sections of this manual.

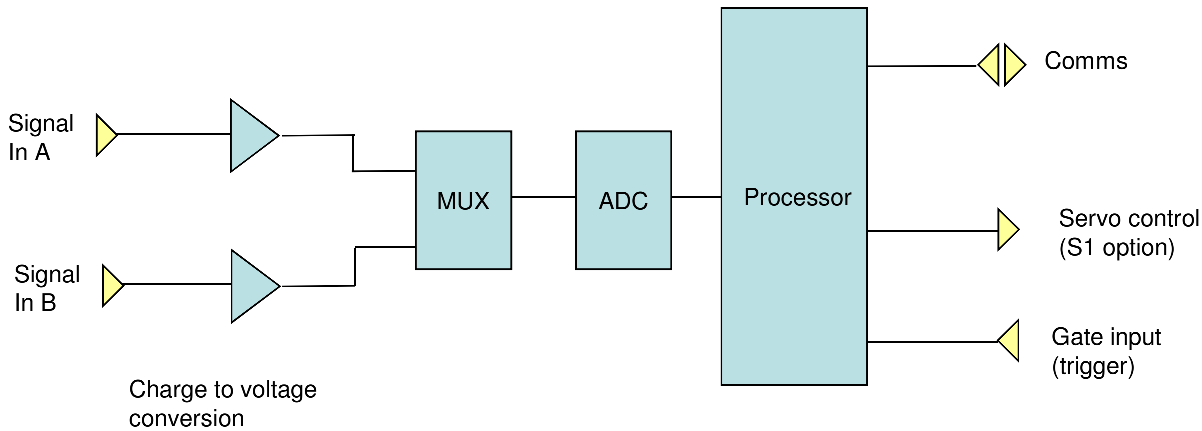


Figure 3. I200 simplified block diagram.

The I200 has a two signal input channels which convert very small currents to measureable voltages. The voltages are measured by an ADC (analog to digital converter). The resulting binary values are converted to current readings in amps by applying calibration factors. These currents can be requested over the communication link, and are also used to drive the monitor outputs. Let's start by looking at the measurement process in a little more detail.

9.1 Current measurement process

Imagine there is a small current that you wish to measure, which may be varying in time, as shown on the following graph.

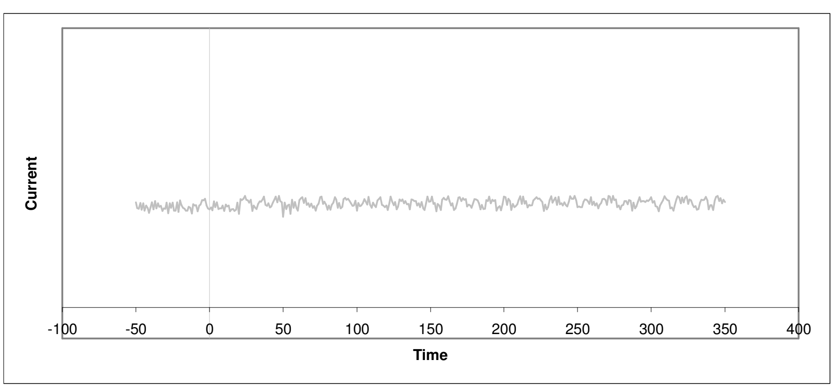


Figure 4. I200 integration: an example current to be measured

A conventional current to voltage conversion method would convert this current into an equivalent voltage, and this voltage would be converted to a number by an ADC (analog to digital converter). However this method is less suitable for measuring very small currents because of signal to noise limitations. The I200 therefore uses a method called gated integration instead.

Imagine that at some point in time (zero on the graph), you start accumulating (integrating) this current on a capacitor. The capacitor will charge up, and an increasing voltage will therefore appear across the capacitor.

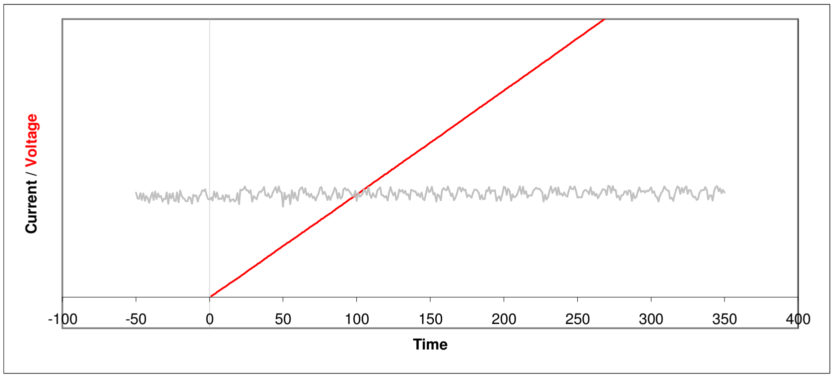


Figure 5. I200 integration: voltage on a capacitor that is connected at time zero

If we measure this voltage with an ADC, we will know the charge on the capacitor at the time of the conversion. If we measure the voltage at two defined times, we will know the increase in charge over a known time interval.

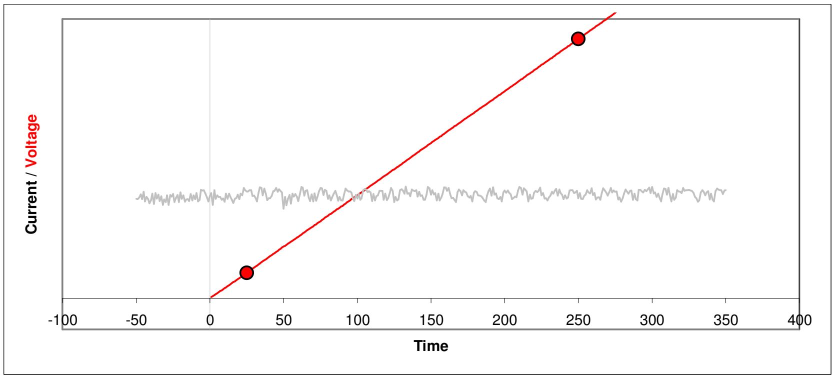


Figure 6. I200 integration: capturing the voltage at two times

From this we know the average current during that time interval, because average current is simply charge divided by time. The time interval is called the integration period.

We cannot allow the voltage on the capacitor to simply increase for ever. The ADC has a specified input voltage range, and there is little point in exceeding it. Therefore we must

discharge the capacitor periodically, and this takes some time, typically 20 µsec. Then we can restart the cycle.

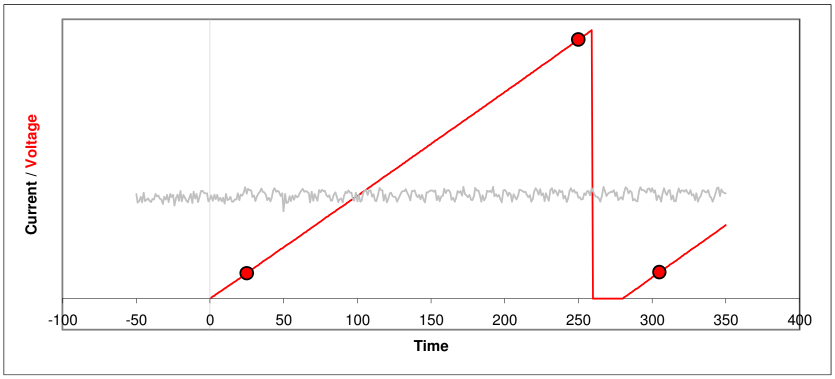


Figure 7. I200 integration: discharging the integration capacitor and starting a new cycle.

The process of charging the capacitor and discharging to reset is called gated integration. The length of the integration can be controlled in the I200 in the range 20 µsec up to 10 seconds, and typical working values are in the range 100 µsec to 1 sec.

Notice that the first ADC conversion does not take place immediately when the integration starts. This is because the signal is unstable just after the reset, so we wait a time called the settle time before making the first conversion. This time is normally set to 20 µsec. The settle time can be adjusted, but it is a detailed parameter that doesn't usually need to be worried about.

We can get a running measure of the current by simply repeating the integration cycle as many times as we want. Each time, we can divide the measurement of charge that is the difference between the ending and starting ADC values by the time interval between them to get the current reading. In the figure, the blue bars indicate the readings; each is the final ADC value minus the starting ADC value for that integration.

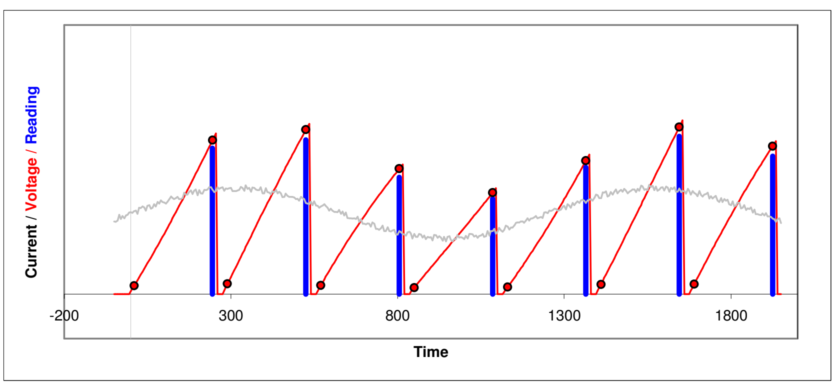


Figure 8 I200 integration: repeated integrations to sample a continuous current signal.

There are some points to note. Firstly, notice that the readings are very clearly linked to the time of their integration. Because of the resets, there is no influence at all from earlier integrations. Next, notice also that we get no information about how the current may have varied within each

integration - we see only the average. Finally, notice that we are not measuring at all during the resets. If you choose the shortest available integration times, the reset time might be a noticeable fraction of the overall time.

Why would you choose any particular integration time? The first consideration is the size of current you expect to measure. For a given charge integrating capacitor, the longer the integration, the smaller is the maximum current you can measure, and the more sensitive the I200 is to very small currents.

The next consideration is timing. If the current you are measuring is only present in a short pulse, there is little point in integrating longer than this, because you will simply be measuring extra noise. If the current is continuous but has variations that you wish to measure, then you must have integrations short enough to be sensitive to the variations, rather than smoothing them out.

The final consideration is filtering. A given integration time, used repeatedly to measure a continuous current, acts as rectangular low-pass filter. This has the property of completely suppressing frequencies in the signal which correspond to the integration period. If you are troubled by 60 Hz noise, for example, then using an integration period of 1/60 seconds will eliminate the problem. So will any integer multiple of that period. A good choice is 100 msec, as this is five times the 50 Hz period, and six times the 60 Hz period.

The I200 provides a lot of flexibility in how measurements are made. Let’s look at some of the parameters.

9.2 Current ranges

You can control the tradeoff between sensitivity to small currents and ability to measure larger currents by selecting the integration time and the feedback capacitor. Longer integration times improve the sensitivity to very small currents, but reduce the maximum current that can be measured. Similarly, the small feedback capacitor should be used to measure small currents, but if you need to measure higher currents, use the large capacitor.

As examples, if you need to measure currents of only a few pA, you will need the small feedback capacitor and integration time in the range 100 msec to 1 sec or more. If you need to measure currents up to tens of µA, you will need to select the large capacitor and use integration times in the order of 100 µsec.

9.3 Triggering

In many cases you will need to coordinate the I200 measurements with external events. You can preset the I200 with all the measurement, then initiate it ready to respond to a trigger signal. Measurements will start as soon as the trigger arrives.

9.4 Self-testing and calibration

The I200 can calibrate itself on both channels and both feedback capacitors fully automatically, and it stores the resulting factors so that it can provide results in physical units (amps or coulombs). You can also turn on the calibration current at any time and direct it to either channel to check that the device is working correctly.

9.5 Servo controller

The I200 with the –S1 servo option is a highly flexible servo controller. You can define a process variable as one of several arithmetic combinations of the measured currents, and the I200 will maintain the process variable by adjusting the value of a control voltage output.

10 Installation

10.1 Mounting

The I200 may be mounted in any orientation, or may be simply placed on a level surface. A fixed mounting to a secure frame is recommended in a permanent installation for best low current performance, as this can be degraded by movement and vibration. Four M3 clear holes are provided in the base flange on a 152 mm by 144 mm rectangular pattern (see figure 2).

The mounting position should allow sufficient access to connectors and cable bend radii. Leave 100mm clearance at either end for mating connectors and cable radii.

Best performance will be achieved if the I200 is in a temperature-controlled environment. No forced-air cooling is required, but free convection should be allowed around the case.

10.2 Grounding and power supply

A secure connection should be made using a ring lug, from the M3 ground lug to local chassis potential. This is the return path for any high voltage discharge passing via the I200.

+24 VDC power should be provided from a suitably-rated power supply with the following minimum performance:

Output voltage	+24 +/- 0.5 VDC
Output current	500 mA minimum, 1500 mA maximum
Ripple and noise	< 100 mV pk-pk, 1 Hz to 1 MHz
Line regulation	< 240 mV

The I200 includes an internal automatically re-setting PTC fuse rated at 1.1 A. However the external supply should in no circumstances be rated higher than the I200 connector limit of 5 A, and a maximum of 2.0 A is recommended.

10.3 Connection to signal source

10.3.1 Typical setup

Figure 9 shows a typical installation in schematic form. Split readout electrodes in a signal source such as an ionization chamber are connected to the two inputs via individual coaxial cables. In this example, an electrode is biased by the auxiliary external high voltage output. A gate signal generated by a remote timing controller, for example, triggers the I200 to start measuring data. Data is transmitted to the host computer system via one of the I200 communications ports.

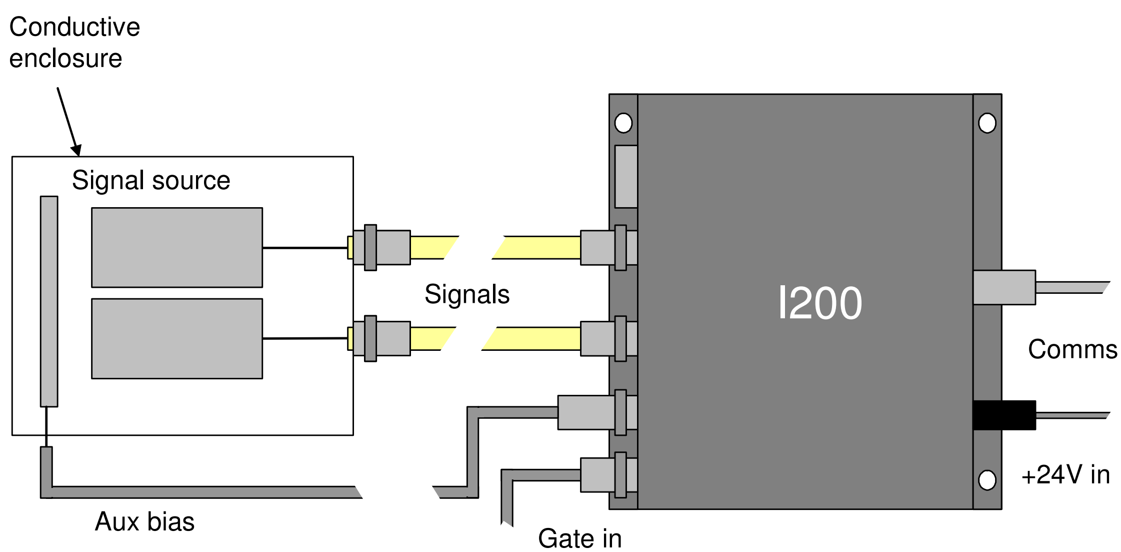


Figure 9. Schematic I200 installation

Refer to section 20 in this manual for general guidance on making low current measurements. The I200 should be located as close to the source of the signal as possible. Long signal cables increase the chances of seeing unwanted signals and noise. A maximum length of 3m is advised. Longer cables may be used, but the lowest detectable current will be increased.

Pyramid Technical Consultants, Inc. does not recommend using the direct USB interface for very low current measurements. Connecting the USB cable causes the chassis to connect to analog ground in the I200, which increases zero noise and drift. Fiber-optic interfacing is optimum for both speed and noise immunity.

10.3.2 Signal cables

If your I200 was supplied with the standard BNC inputs, you should use low-noise coaxial cable to connect to the signal source. A cable which has been tested and found to give good immunity

to vibration-induced noise is Belden 9223 010100 low-noise RG-58. Normal coaxial cable should not be used, as this will degrade significantly your ability to measure small currents.

If your I200 was supplied with the triaxial connector option, you should use triaxial cable. A recommended type is Trompeter TRC 50-2. Three lug triaxial connectors are used on the I200. The signal core and the inner guard screen are at internal analog ground potential, with the connection made in the I200. The shared potential of the guard and signal conductor are important for minimization of leakage currents and triboelectric noise. The outer screen is at I200 chassis potential. The inner guard should be brought as close as possible to the point of connection to the signal source, but should not be connected to anything at that end. The outer screen should generally terminate on the grounded enclosure of the signal source.

If you have an I200 with triaxial connectors, but wish to adapt to low-noise coaxial cable, then you will need an adaptor, which connects through the core and outer screen, but does not connect the inner triax guard. A suitable adaptor is Trompeter ADBJ20-E2-PL75.

10.3.3 Signal current path

Figure 10 illustrates how the current you are measuring passes along the cable inner conductor to the I200 input. It effectively flows between the terminals of the input amplifier to the local analog ground, due to the amplifier virtual earth, then out to the case of the I200. The current then returns to the current source along the outer screen of the signal cable. If you need to break the continuity of the outer screen for noise suppression reasons, then you must ensure there is an alternative path between the I200 and the signal source, or you will see no current.

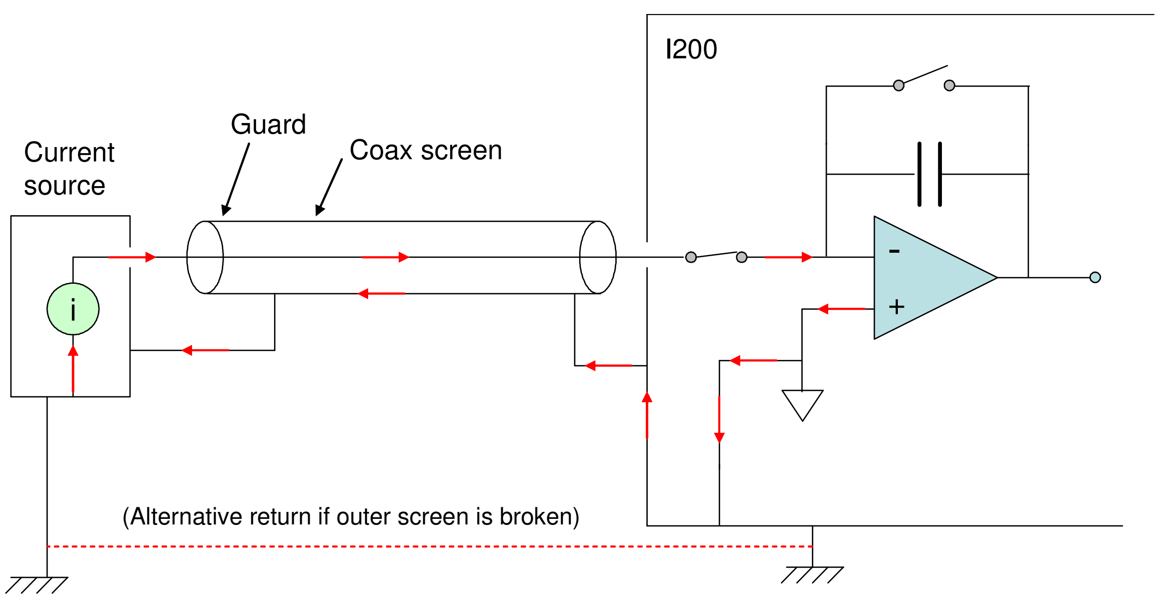


Figure 10. Path of measured current (coax inputs).

11 Getting Started in ASCII Mode

Before installing the I200 in its final location, and if it is the first time you have used an I200, we recommend that you familiarize yourself with its operation on the bench. You can check the unit powers up correctly, establish communications, run the internal calibration procedure, and read the internal calibration current.

1) Inspect the unit carefully to ensure there is no evidence of shipping damage. If there appears to be damage, or you are in doubt, contact your supplier before proceeding.

2) Connect 24 V DC power but no other connections. The power LED should illuminate when the power is applied, and the status and link LEDs will cycle through green, orange and red (see section 17.4).

3) Make a connection to a PC serial port. A three wire lead terminated in a six-pin mini-DIN male connector (PS/2 mouse type) and a nine-pin D female is required, as in the figure below. Pins are shown looking at the face of the connectors. When the connector is pushed home in the I200, the “optical” LED should extinguish and the “RS232” should illuminate. Connecting to this port forces the I200 to be a listening device.

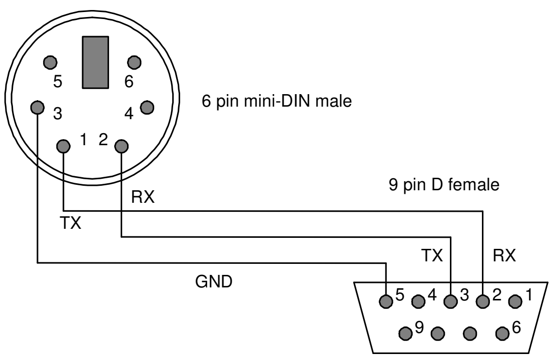


Figure 11. RS232 connection cable from the I200 to a PC serial port (DB9).

4) Set the address rotary switch to position “4” (address 4) and the mode rotary switch to position “6” (ASCII communication, 115 kbps). The address value is just for the example – you can choose any number from 1 to 15.

5) Configure a Windows Hyperterminal session to use COM1 (or other available port on your PC) as shown in the following figures. A suitable Hyperterminal file is provided on the I200 software CD-ROM. Unfortunately, Windows versions since Vista do not include Hyperterminal. To remedy this, you can either move the relevant files (hypertrm.dll and hypertrm.exe) over from a Windows XP system, or use one of the various free terminal emulation programs such as PuTTY or Realterm.

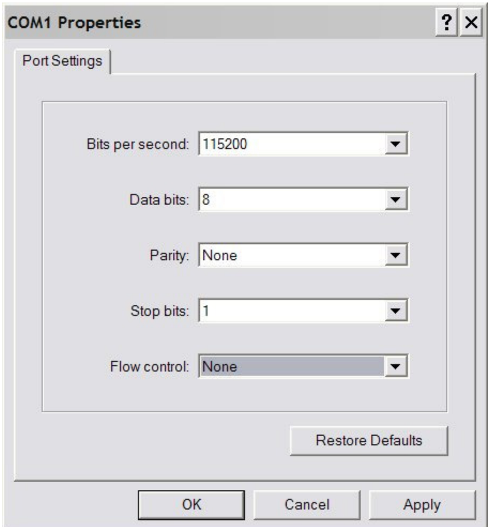


Figure 12. Hyperterminal COM port setup.

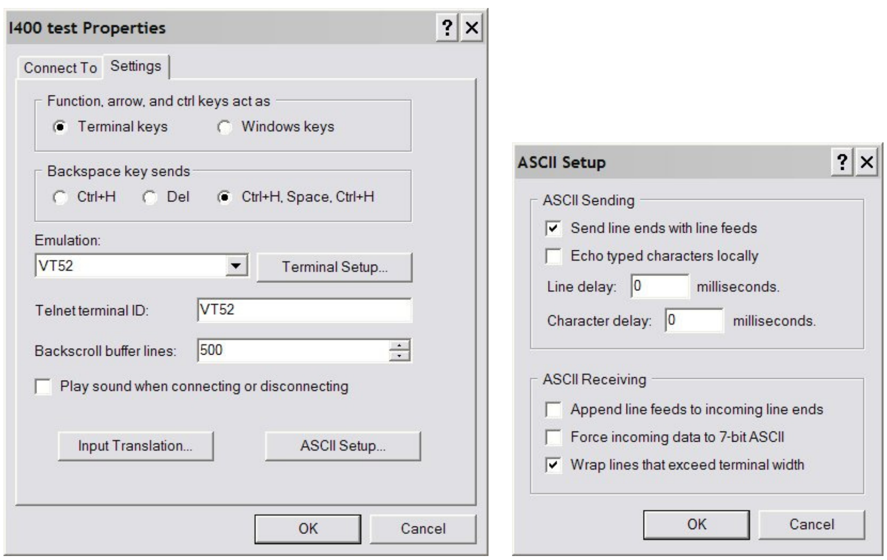


Figure 13. Hyperterminal terminal settings

6) Type “#?<CR>” to query the active listener. You should get the response “4”. You are communicating successfully with the I200. If you hear your computer’s bell sound when you send the string, the I200 did not understand it, probably because there was a typing error. If the I200 does not echo correctly, either the terminal settings or the I200 switch settings are likely to be wrong. Check them and retry until you see the characters echo correctly. If you make any errors while typing, use the backspace key and re-type from the error.

7) Type “calib:gain<CR>”. The characters can be upper or lower case. The I200 will perform its internal calibration sequence.

8) Type “calib:gain?<CR>”. The I200 will return the gain factors for the two channels.

9) Type “read:curr?<CR>”. The I200 will do a measurement and return the integration period it used and the measured current values for two channels. The current values should be close to

background. The default integration period on power-up is the one that gives a one microamp full scale, for example 0.1 msec for a 10 pF feedback capacitor, 10 msec for a 1000 pF feedback capacitor and so on. If you repeat “read:curr?<CR>” a few times you should see the readings change due to background noise.

10) Type “calib:source 1<CR>”. This turns on the internal 500 nA calibration currents to each channel. Type read:curr?<CR>” to read this current. You should see values very close to 5.0e-7 A.

11) Type “syst:password 12345”. You are now in administrator mode and able to alter some important parameters. The I200 will leave administrator mode when it is reset or the power is cycled.

12) If your I200 has the external high voltage bias option, type “conf:hivo:ext:max 100”. This establishes 100V as the maximum value that can be set on the auxiliary HV supply. The value is retained indefinitely in EEPROM until you change it. Ensure nothing is connected to the signal inputs nor the external HV bias output. Type “conf:hivo:ext:volt 25<CR>”. This will turn on the high voltage at 25 V and the “HV on” LED will illuminate.

14) Type “*rst<CR>” to reset the I200. Your unit is functioning correctly and is ready to be integrated into your system.

15) If you wish to explore the ASCII communication capabilities of the I200 more fully, refer to the commands list in section 21. You may also wish to try out the terminal mode, which provides feedback from the I200 to every message you send, not just query messages, and is therefore more user-friendly. The screenshot below illustrates this. An “OK” response is returned immediately by the I200 for every valid command. If the message was a query, such as “read:curr?” this is followed by the data when it becomes available.

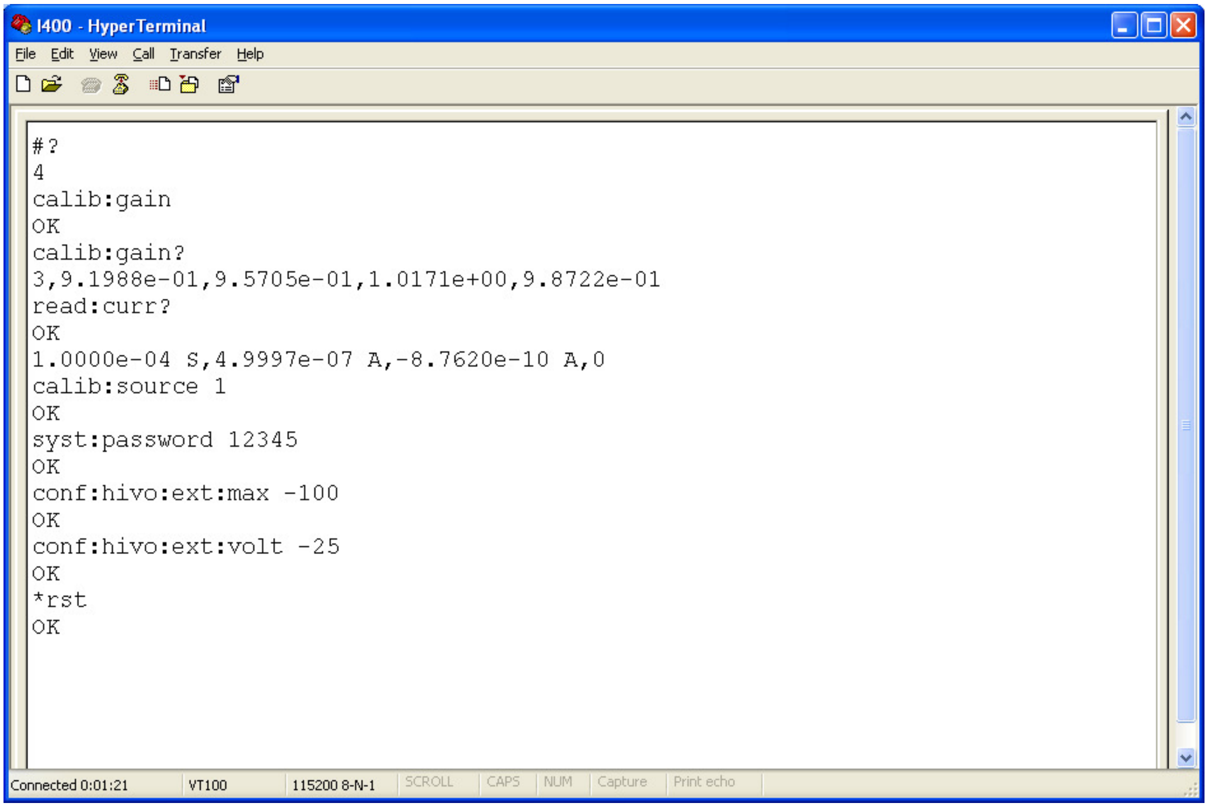


Figure 14. Example Hyperterminal session (terminal mode)

12 Getting Started using the PSI Diagnostic Host Program

The PSI Diagnostic is a stand-alone program which allows you to read, graph and log data from the I200, and set all the important acquisition control parameters. It supports communication via any of the interfaces. For some applications it may be adequate for all of your data acquisition needs.

12.1 Installing the PSI Diagnostic Program

Your I200 was shipped with a USB memory stick with the installation files you need. We recommend that you copy the files into a directory on your host PC. The software is updated regularly to add new features, and the new versions are generally compatible with prior hardware and firmware versions. Check the Pyramid Technical Consultants, Inc. web site at www.ptcusa.com for the latest versions of the Diagnostic, which are available for download at no charge.

The program runs under the Microsoft Windows operating system with the 3.5 .NET framework. This has to be installed before the PSI Diagnostic. All new Windows PCs have .NET already installed. It can be downloaded from the Microsoft web site at no charge.

Install the PSI Diagnostic by running the PTCDiagnosticSetup.msi installer, and following the screen prompts. Once the program has installed, you can run it at once. It will allow you to connect to the I200, and, depending upon your interface setup, multiple additional devices at the same time. The Diagnostic uses the concepts of ports and loops to organize the connected devices. A port is a communications channel from your PS, such as a COM port, a USB port or and Ethernet port. Each port can be a channel to one or more loops, and each loop may contain up to 15 devices.

1) Inspect the unit carefully to ensure there is no evidence of shipping damage. If there appears to be damage, or you are in doubt, contact your supplier before proceeding.

2) Connect 24 V DC power but no other connections. The power LED should illuminate when the power is applied, and the status and link LEDs will cycle through green, orange and red (see section 17.4).

3) It is simplest to connect the I200 directly to the PC via its RS-232 or USB ports (see figures 15 and 16). Using the USB interface, you must install the USB driver (see section 13). If you are using RS-232, set the mode switch to position 2 (115 kbps binary). If you are using USB, set it to position 1 (3 Mbps binary). The address switch can be set to anything between 1 and 15.

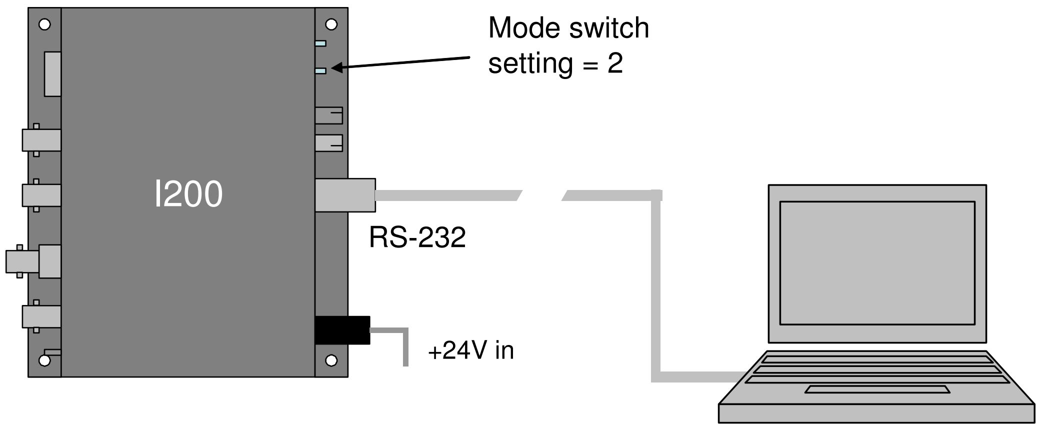


Figure 15. Direct RS-232 connection to the I200.

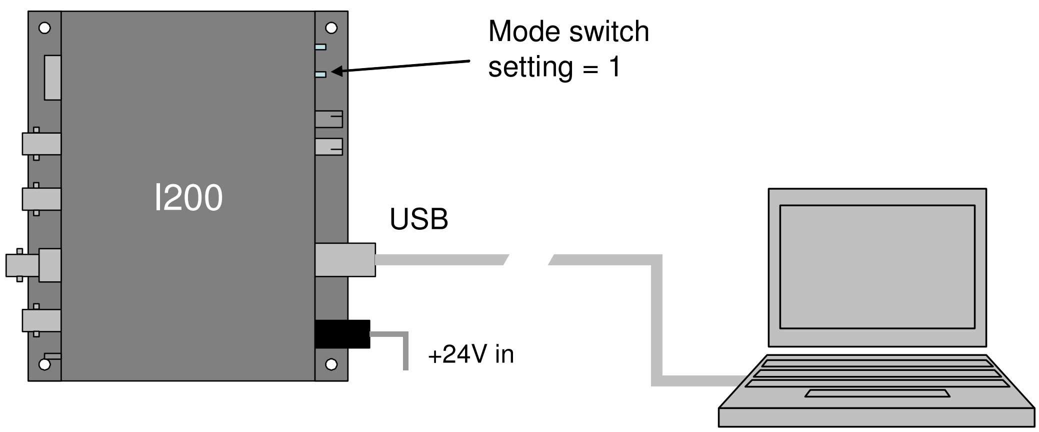


Figure 16. Direct USB connection to the I200.

The Diagnostic will see this simple configuration as a loop with just a single device on it. Because the direct RS-232 or USB connection does not allow other devices to be seen through that port, the I200 appears as both a loop and a device on that loop. Contrast this to the situation where you have a loop controller, such as the Pyramid Technical Consultants, Inc. A200, A300 or A500 devices, and the I200 is connected to the controller via a fiber-optic loop. In this case the loop controller is identified as the loop, and the I200 as a device on the loop.

4) Start the PSI Diagnostic. It will search the available ports and present a search a list. Figure 11 shows a case where the program found two serial ports, a connected USB device (the I200) and a local area network adaptor. It will search for loops and devices on all checked options.

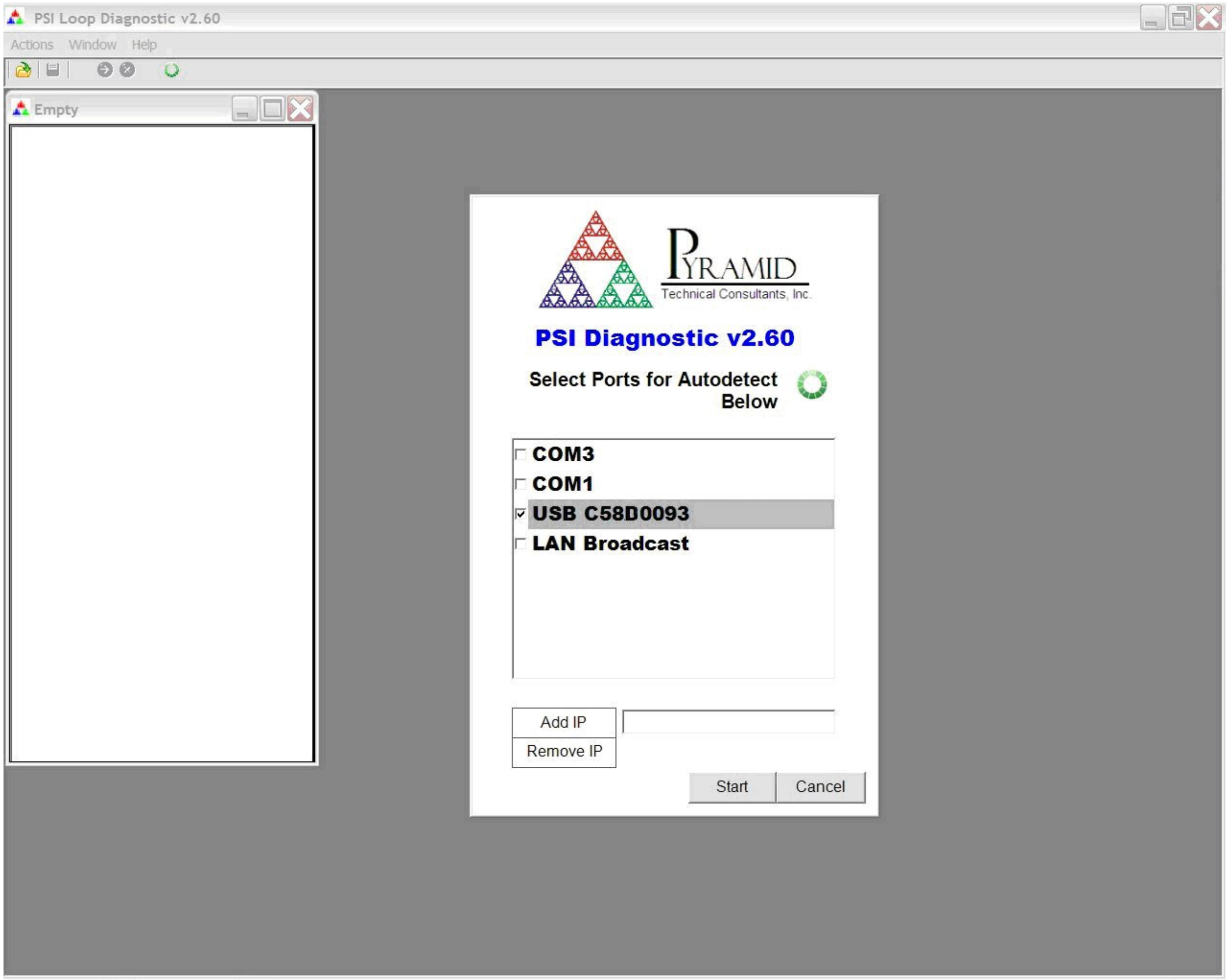


Figure 17. PSI Diagnostic Search Utility

A few seconds after you click the "Start" button, the program should find the I200 (plus any other devices). Clicking on the I200 entry in the explorer list will open the I200 window (figure 18). In the figure the I200 is connected via an A500 controller , rather than directly via USB. The device will be acquiring data using default settings and you should see background noise values for both channels. You can display the signals either as a scrolling current against time graph (like a chart recorder) or as an analog bargraph. If the I200 is not acquiring data, click the "Initiate" button to start the acquisition. Toggle to one of the fixed Y scales if you want to inhibit autoscaling of the graph.

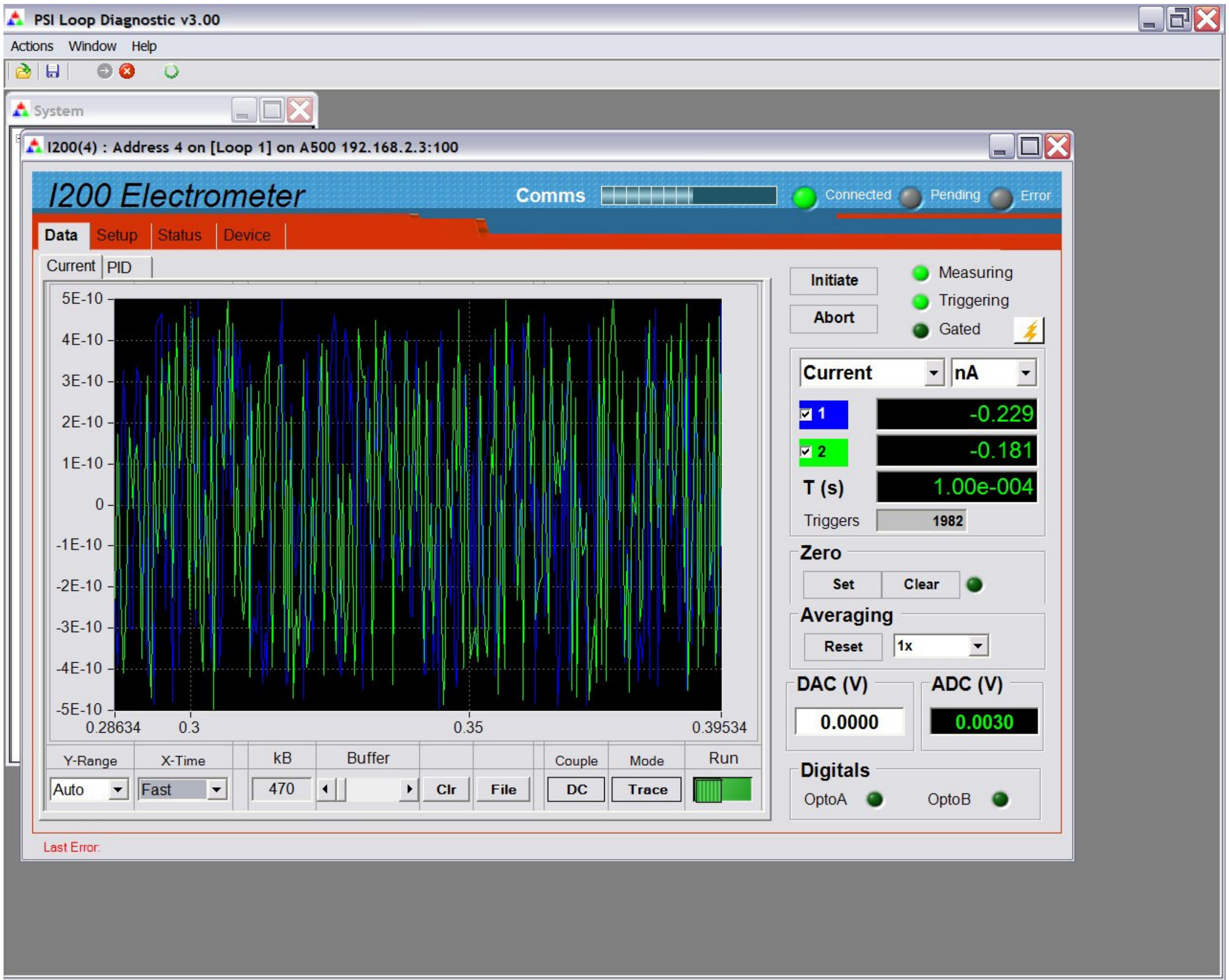


Figure 18. PSI Diagnostic Data/current tab.

5) Click on the “Setup” tab. Here you can adjust measurement parameters such as integration period, feedback capacitor, set the auxiliary high voltage, and use the built-in calibration facility.

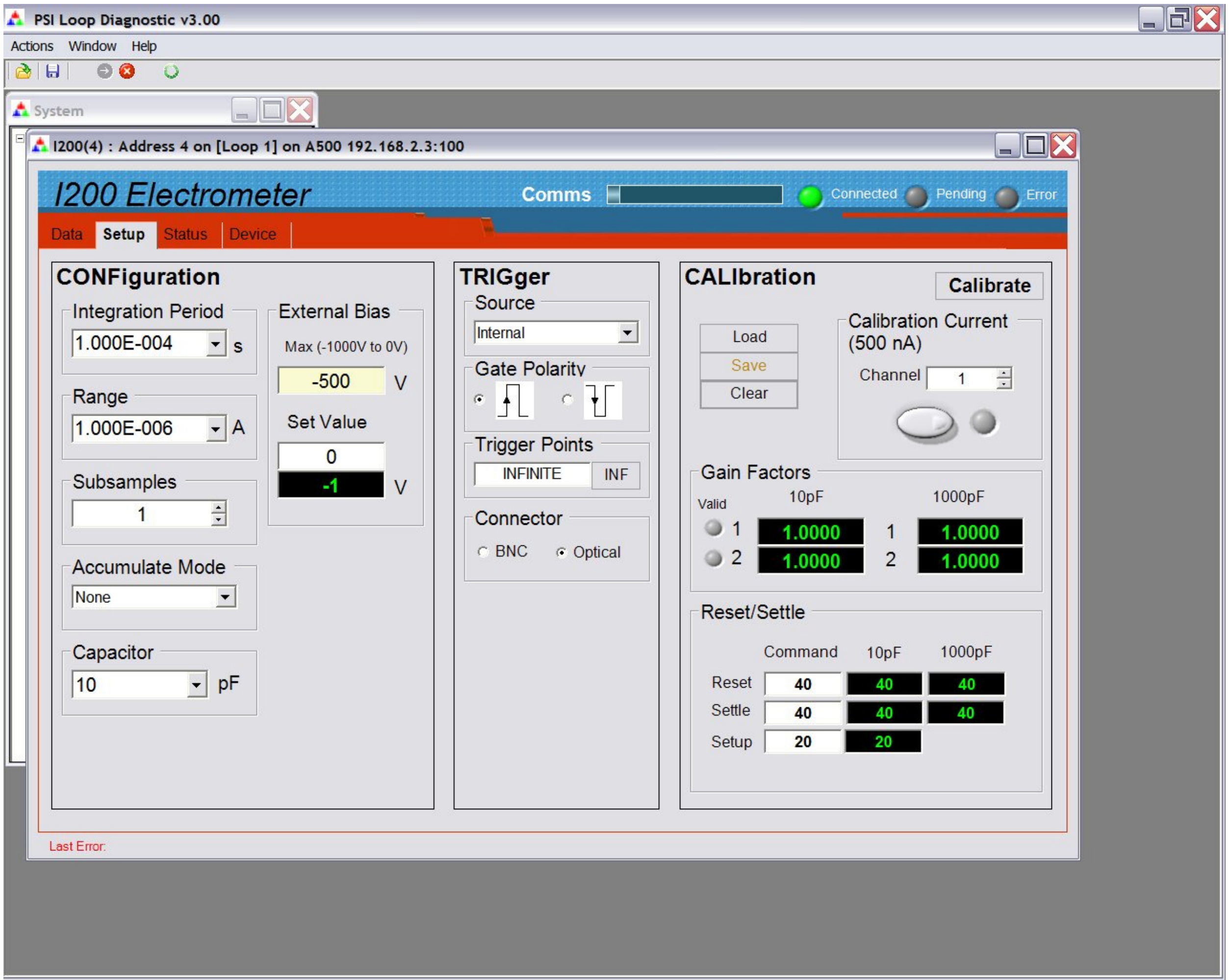


Figure 19. PSI Diagnostic: Setup tab showing default settings.

Try the following tests to become familiar with the I200:

Click the "Calibrate" button. After a few seconds you should see the gain factors updated.

Click the calibration current button and select a channel. If you return to the data tab, you should see the 500 nA calibration current on that channel. Try moving it to the other channel. If the calibration current is overrange (current reading is shown in red text), reduce the integration period to bring it into range.

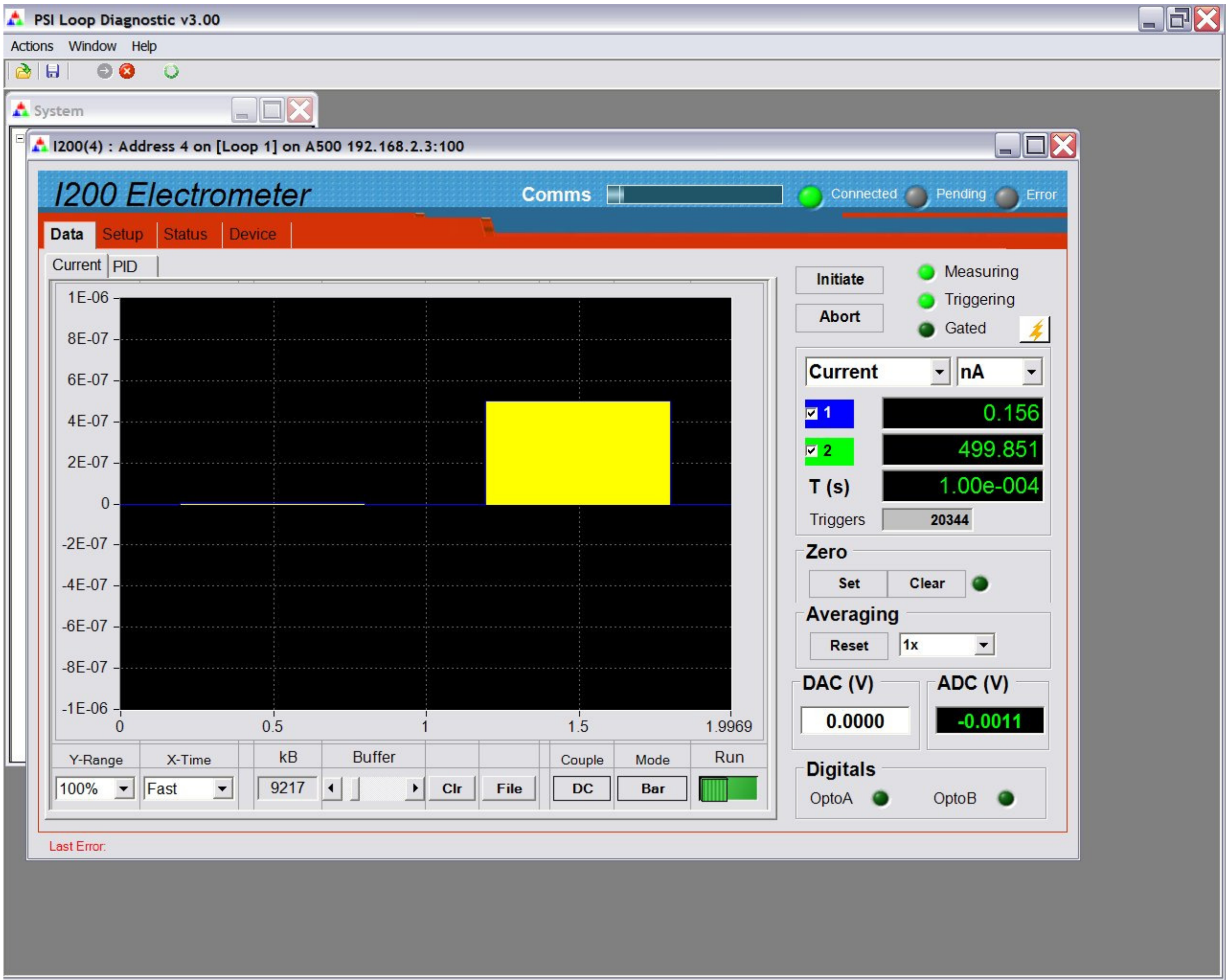


Figure 20. Internal calibration current routed to channel 2, bargraph display format.

With the small value feedback capacitor selected, set an integration time of one second. You should now see very low noise on both inputs, a variation generally less than 0.1 pA.

Click on the "Device" tab. You can check the communication link status and verify the versions of the hardware and firmware. On the right is the firmware update utility. You can use this to download firmware updates (.hex files) downloaded from the Pyramid Technical Consultants, Inc. web site.

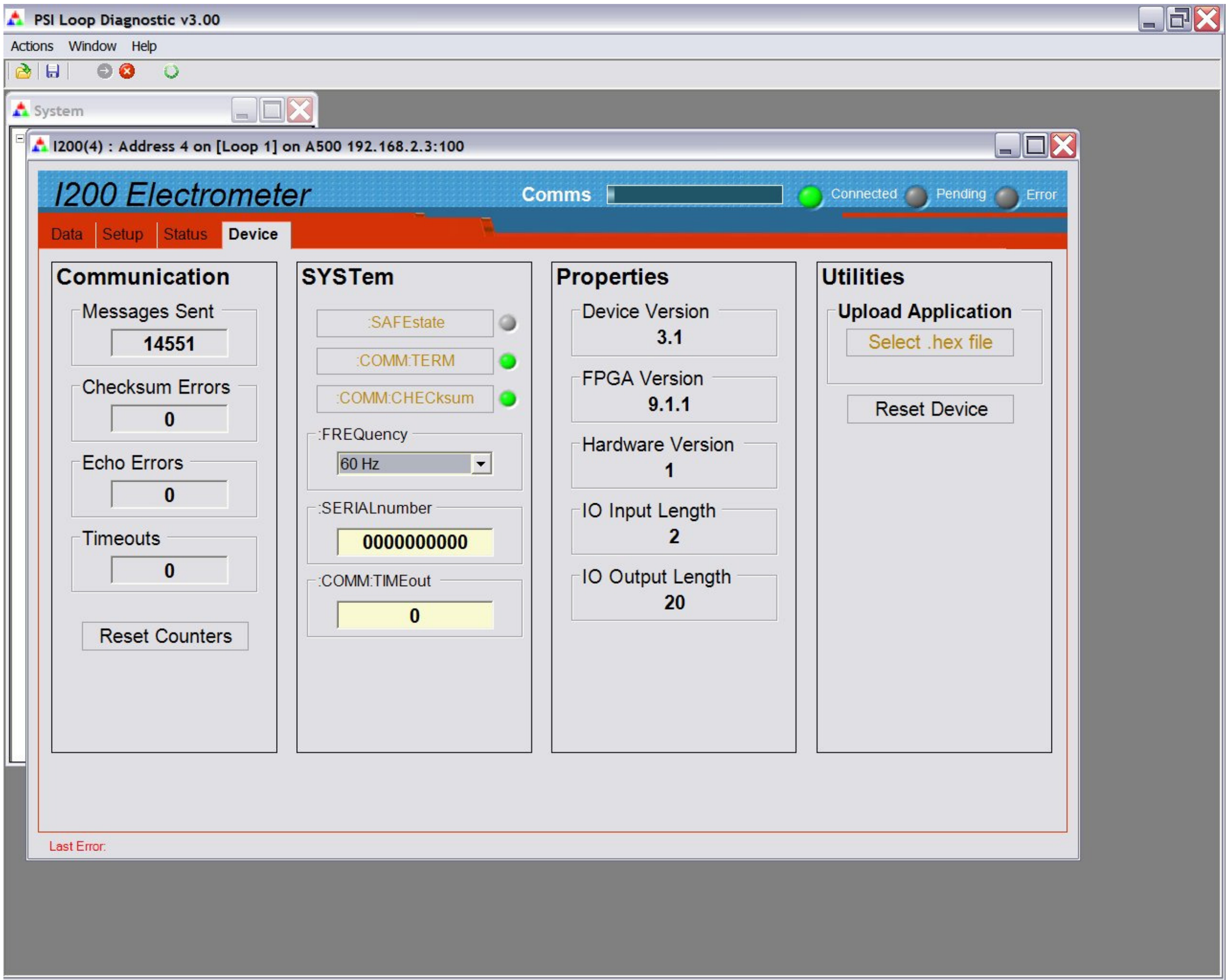


Figure 21. Device tab, showing firmware update utility controls.

If you have the –S1 servo control option, then you will be able to access the relevant controls on the PID sub-tab of the data tab. Here you can control the precision DAC output voltage, sweep the DAC over a range and look at the resulting response on the current inputs, and start a proportional-integral servo loop to lock the current (or combination of the two currents) to a particular value by controlling the DAC. See section 22 for full details of the servo controller function.

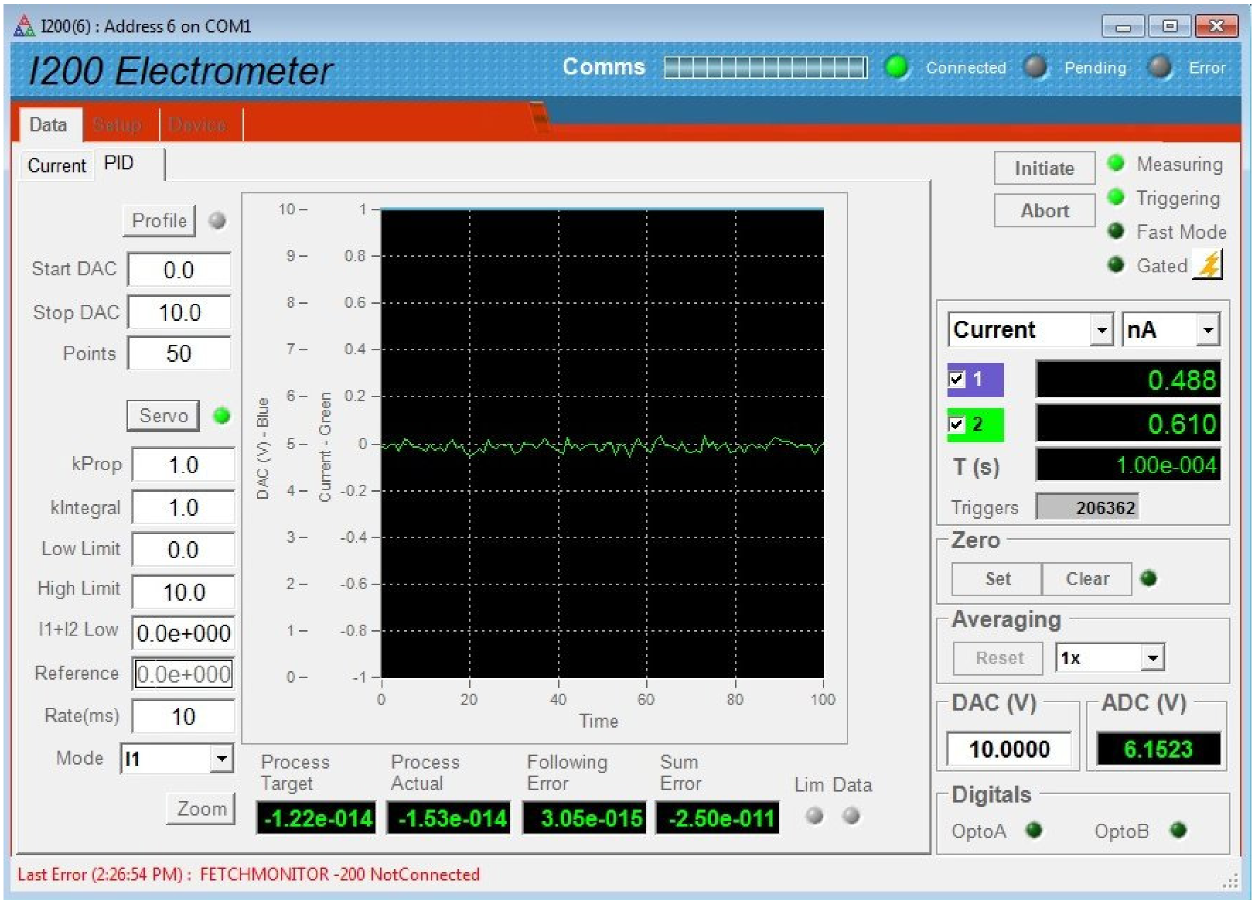


Figure 22. Data/PID tab, showing DAC output and PI servo controls.

13 USB Installation

13.1 Windows XP Installation

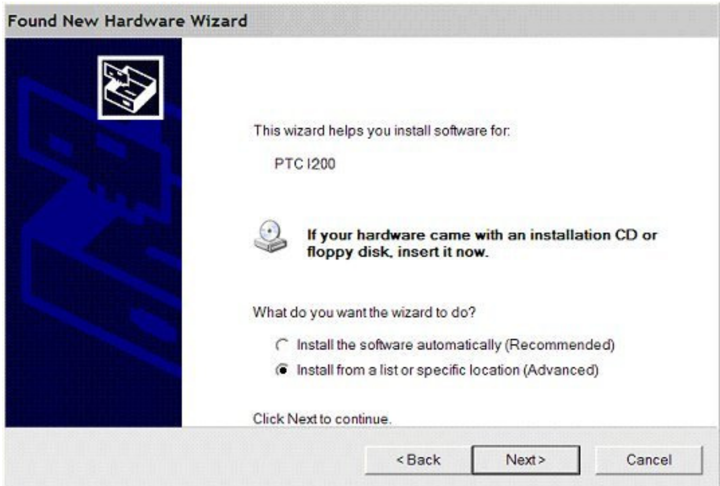
If you intend to use the USB interface, you must install the appropriate drivers on your computer. Each I200 is identified on USB by a vendor identification (VID), a product identification (PID) and the unit serial number. All I200s have the same VID (0403, indicating the USB interface chip vendor, FTDI Ltd) and PID (C58D, indicating the I200 product) but have a unique serial number. Microsoft Windows will recognize when a device with a new combination is connected for the first time, and launch the "Found New Hardware" wizard.

The selection of files installed by the Wizard is guided by information in the file PTC.INF. There are two types of driver for the FTDI chip used in the I200, COM and DLL. It is important not to let the wizard install the COM driver, which it tends to do if you take defaults. The PSI Diagnostic software requires the DLL driver.

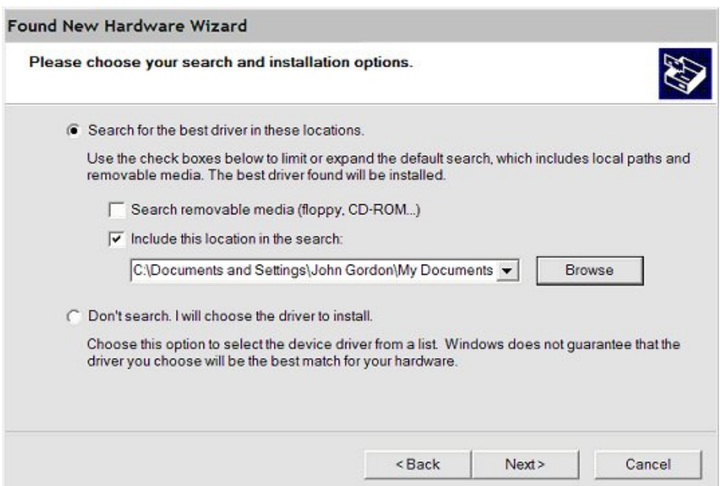
The wizard should be run as follows (Windows XP):

1) Don't let the wizard look for drivers on the internet.

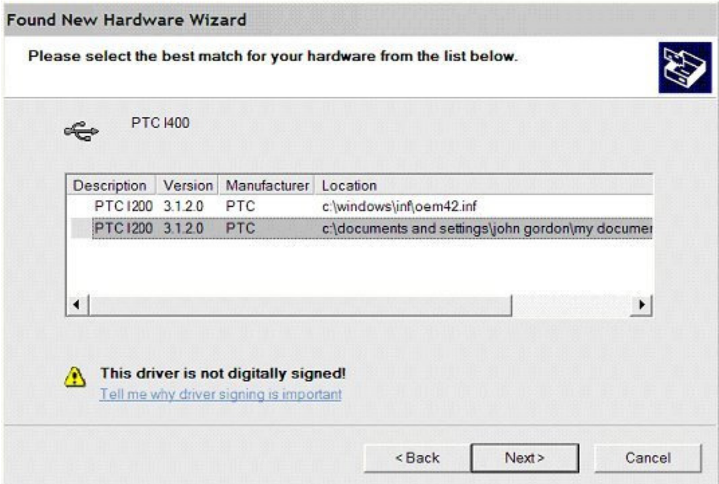
2) Select installation from a specific location.



3) Using the browse option, navigate to the location of the PTC.INF file on the memory key supplied with the I200, or to the appropriate directory on your computer. The driver files and uninstall files should be in the same directory as PTC.INF.



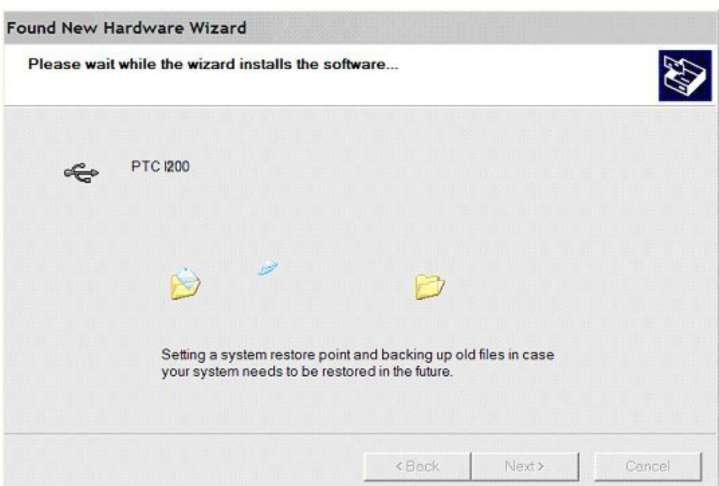
The wizard may find other .inf files which also have valid entries, depending on the history of your PC. Select the PTC.INF file.



If there is only one valid entry, the wizard will proceed directly to the installation phase.

4) Allow the installation to continue despite the driver not having the Windows Logo approval.

5) The driver installation should now occur.



When installation is complete the “Your new hardware is installed and ready to use” message balloon should appear. You may be prompted to reboot your PC.

Note that Windows XP recognizes each individual I200 as a different device because it has a unique serial number. Therefore you will be prompted to install the driver again if you connect another I200. Simply repeat the process outlined above.

13.2 Windows 7 Installation Differences

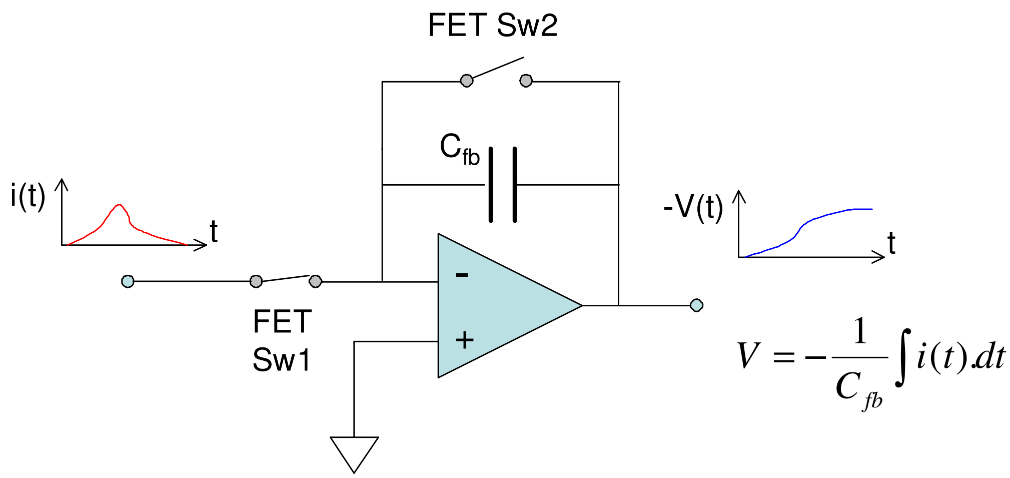
Windows 7 has a more automated driver installation process which searches the internet and your computer for an suitable driver. If you have installed other Pyramid Technical Consultants USB devices in the past on the computer, Windows 7 will usually recognize that the same driver is appropriate. Otherwise you will need to direct it to the driver location. With the I200 connected to a USB port, open Device Manager and find the I200 under Universal Serial Bus controllers. Double click to open the Properties dialog, and select Update Driver … You can then navigate to the correct directory and install the driver.

If you do not see the I200 in the list of devices, this may mean that the FTDI chip is not programmed with the correct PID. You can still use the USB port. Look for the FTDI Serial Converter device in the list, and proceed as above.

14 Principle of Operation

14.1 Gated Integrators

The I200 uses the gated integrator method. This is a particularly effective technique for measuring small amounts of electrical charge. The charge accumulates on a small low-leakage capacitor in the feedback loop of an operational amplifier, with the result that the voltage at the amplifier output is the integral of the current that flows into the input (figure 23).



$$V = -\frac{1}{C_{fb}} \int i(t).dt$$

Figure 23. The basic gated integrator circuit.

Integration starts when FET switch Sw2 is opened. The current into the input can be negative or positive. The voltage at the output of the amplifier is sampled and digitized by an ADC. Calibration with a stable, accurately known test current allows variables such as the exact size of the feedback capacitor, buffer amplifier gain and ADC gain to be compensated in a single gain factor. At any time t after the start of the integration, the accumulated charge is thus given by

$$q_{meas} = k(ADC_t - ADC_{start})$$

where k is the gain factor. The data can also be presented as an average current in the time interval between the readings, because that interval is known accurately.

$$i_{meas} = \frac{k(ADC_t - ADC_{start})}{t}$$

As the integration proceeds, this measure of the average current achieves increasing signal to noise ratio, as more charge is accumulated and the low pass filtering roll-off due to the increasing integration time moves to lower frequency.

The inherent integration is very effective in reducing noise, being in effect a rectangular low-pass filter with -3dB response at $0.44/t_n$ Hz and zero response at N/t Hz, N=1,2,3,…. Known

dominant noise frequencies, for example line voltage interference at 50 Hz or 60 Hz, can be completely suppressed by choosing t_{per} = 1/50 or 1/60 seconds, or integer multiples thereof.

14.2 Sub-sampling

Readings are available at times $n.t_{sub}$ during the integration, where n = 1… N with N the number of sub-samples requested in the integration period, t_{per}, and $t_{sub} = t_{per} / N$. This method is most effective when you have a host system that can handle higher data rates, such as the A500 real-time loop controller. Figure 24 illustrates how a portion of the input waveform is integrated by the opening of Sw2. The plots are (from the top) an illustrative input current waveform; the integrator gate Sw2 state, the integrator output with ADC sample points shown; the ADC readings. ADC readings are taken for the sub-samples, with ADC_{start} being subtracted from each subsequent sample to produce a charge reading.

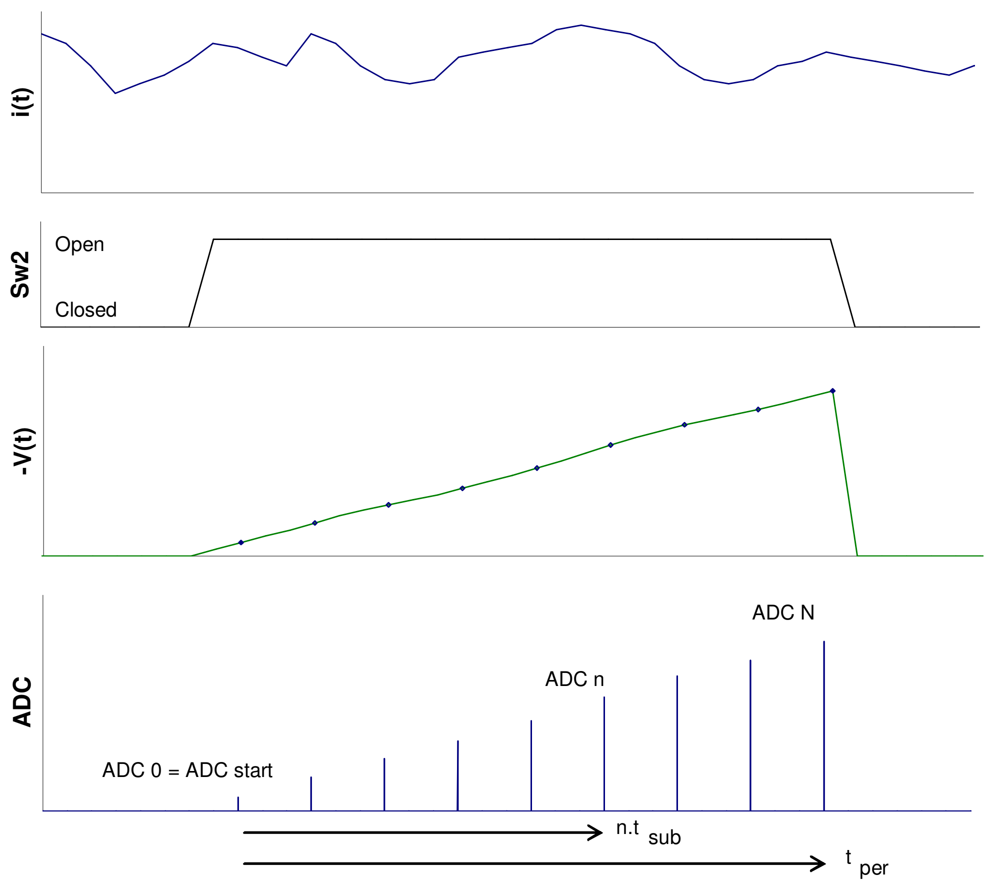


Figure 24. Data acquisition timing diagram.

Integration cannot proceed indefinitely because the charge amplifier output voltage cannot exceed its voltage supply rails. It is necessary to reset the integrator periodically, at a rate determined by the average input current and the size of the feedback capacitor. After the defined

integration period, t_{per}, switch Sw2 closes to short the feedback capacitor and release the charge, so zeroing the integrator ready for the next cycle.

The reset time needs to be sufficient to completely clear the accumulated charge through the FET on resistance, and thus depends upon the size of the feedback capacitor. There is also a short settle time allowed after opening Sw2 to start the integration before the start ADC reading is taken, to allow transients to die away. A further time associated with the reset, called the setup time, accounts for the fact that the ADC conversions are not generally exactly aligned with the end of the specified integration period.

14.3 I200 Circuit Overview

Two identical gated integrator channels are multiplexed into a 16 bit bipolar ADC. The digitized charge values are managed by a microcontroller/FPGA combination which handles all measurement timing control, calibration, data conversion and communications to the user's host computer system. Communications can be via RS-232, USB or fiber-optic using ASCII protocols based upon SCPI, or binary protocols. RS-232 and USB are intended for direct connection to a host PC. The fiber-optic interface allows a full loop-based system, with multiple individually-addressed devices.

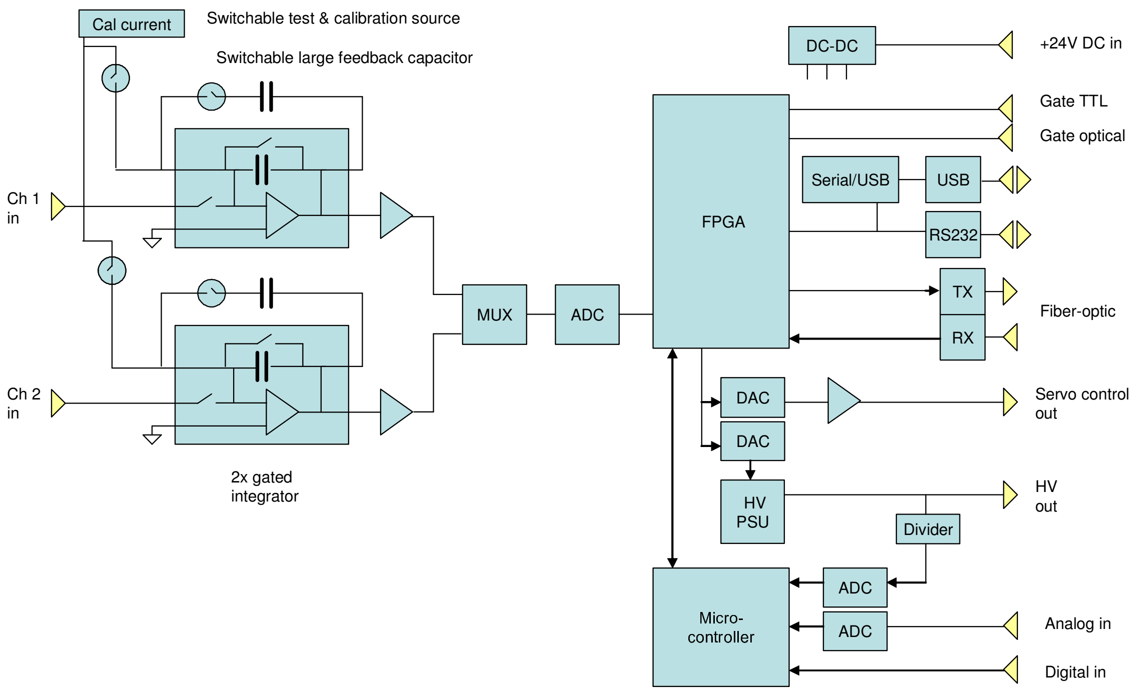


Figure 25. I200 block schematic.

The two integrators are operated in synchronization. The output voltages are multiplexed into the ADC in rapid succession, to be digitzed by successive conversions. The time offset between the two inputs is 4 microseconds. Because the ADC conversions can occur much more rapidly that the integration period, the I200 can use sub-integration period sampling to track the charge build-up on the feedback capacitors between resets, as described in the previous section. This enables several useful measurement techniques and features. When the average current being measured is very low, so that a long integration period is needed to get a precise value, sub-integration sampling allows intermediate current values to be returned, rather than having to wait for the integration to end before getting a new reading. Time-resolved data is available from within the integration period. This allows, given adequate signal to noise ratio, reconstruction of the shape of a pulse that occurred within one integration period.

A precision 500 nA calibration current source is built in to the I200. It can be switched into either channel. Confirmation of correct operation and gain calibration can be performed under remote control.

Each integrator circuit has a FET switch in series in its input, in addition to the reset switch in its feedback loop. Operation of this switch in combination with the reset switch allows an integration mode where no charge is missed, even during resets. This is described in the section on charge accumulation measurements.

The on-board processor can monitor several additional parameters as well as the integrator outputs.

External auxiliary HV output, via a voltage divider

Two opto-coupled digital input lines

Analog input to a 10-bit ADC (buffered and scaled to read 0 – 10V from a pin on the auxiliary I/) connector)

The I200–S1 servo control version provides a high-precision buffered 16 bit 0 to +10V output for process control. The output can be commanded directly, or placed under servo control using an error value derived from the current inputs. The servo is executed in the microcontroller using floating point arithmetic. Further details on the servo control option can be found in section 22.

Making Measurements

14.4 Current and charge ranges

The I200 measures the charge q that in integrated on the feedback capacitor. The exact integration time t_{per} is returned with every reading, so the values are simply converted to the average current during the integration from

$$i = \frac{q}{t_{per}}$$

The selection of feedback capacitor, integration period and programmable gain amplifier setting determines the maximum current i_{max} that can be measured, limited by the ten volt range of the input amplifier.

$$i_{\max} = \frac{10C_{fb}}{t_{per}}$$

The table gives the nominal full scale measurement ranges for the standard feedback capacitors and three example integration periods. You are of course free to select any integration period in the available span (20 µsec to 10 sec). The actual full scale ranges will differ slightly from channel to channel due to the small conversion gain variation (due in turn to small differences in the feedback capacitor values) that is compensated by the I200 calibration factors. Which ranges are useful will of course be limited by the offsets and noise levels in your system.

Capacitor	FS range (C)	FS range t_{per} = 100 µsec	FS range (A) t_{per} = 10 msec	FS range (A) t_{per} = 1 sec
10 pF	1e-10	1 µA	10 nA	100 pA
1000 pF	1e-8	100 µA	1 µA	10 nA

In addition to the charges readings in coulombs and integration period in seconds, the returned data also includes a bitwise overrange byte that flags any channels where the reading has gone overrange (ADC value greater than 95% of full scale). The lower two bits indicate overrange for channel A and channel B.

LSB	Input A overrange
	Input B overrange
MSB	

In general you should check the maximum current that you can measure for a given set of conditions if it is very important that you never overrange, and provide some margin as needed.

14.5 Integrator Control

The I200 allows the user a high degree of control over the integration cycle, so you can optimize the operation of the device for your application. The various times that can be programmed are shown schematically in figure 20. The pairs of ADC read pulses correspond to the capture of the two input channels. They are about 5 µsec apart.

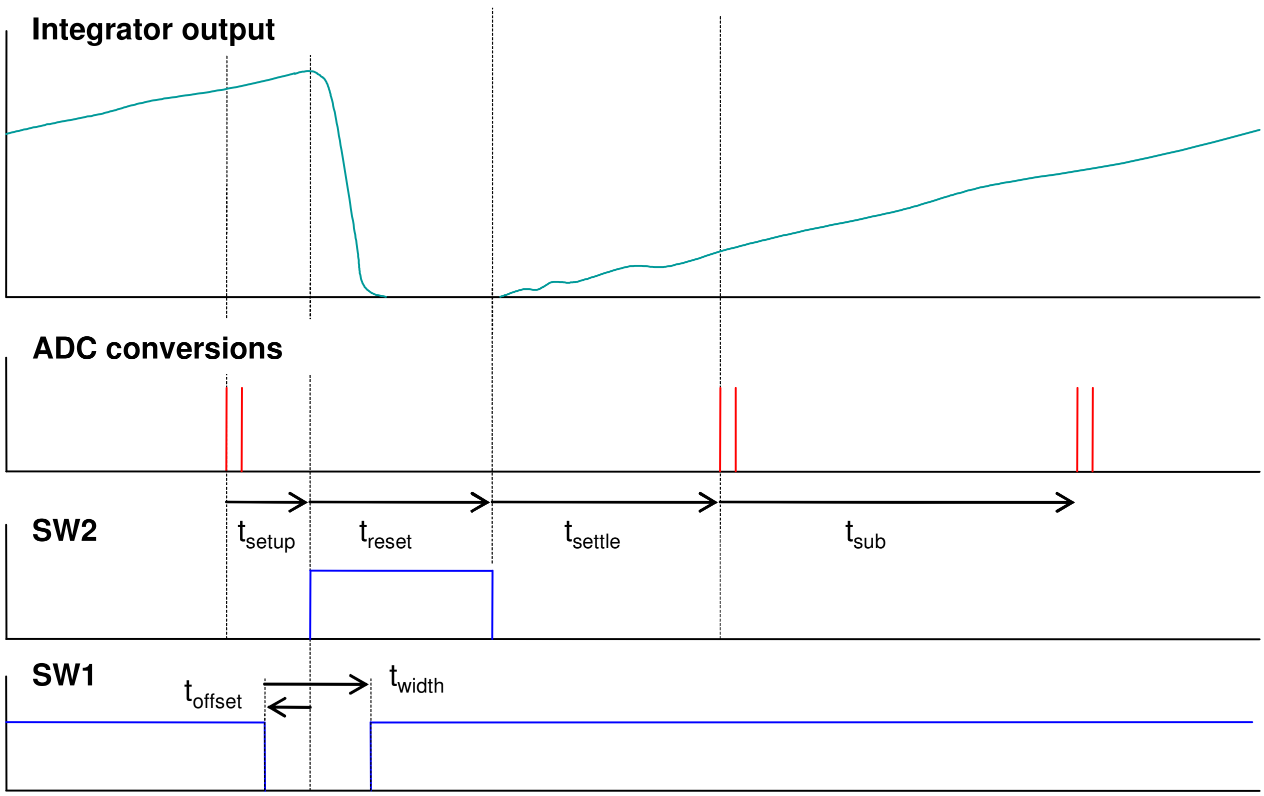


Figure 26. Programmable times for the integrator reset process.

t_{per}	The total integration period, measured between corresponding first and last ADC readings. Minimum 100 µsec, maximum 10 sec.
t_{sub}	The subsample period. $t_{sub} = t_{per}/n$, where n is the number of subsamples. Minimum 100 µsec, defined by the subsample number.
t_{setup}	The time between the last ADC reading in an integration cycle and the closing of SW2 to reset the integrator. This has to be set long enough to ensure that the last ADC readings are not affected by the closing of SW2.
t_{reset}	The time the integrator is held in reset. This has to be set long enough to clear all the charge from the feedback capacitor.
t_{settle}	The time allowed after the integrator reset for the integrator output to settle, before the first (zero) ADC reading is taken. This has to be set long enough to clear the initial noisier part of the integrator ramp, assuming the best measurement precision is required.

	.
t_{offset}	The offset (positive, or negative as shown in figure 26) of the SW1 opening from the start of the integrator reset. On the PSI Diagnostic this is called SW1 time (Front).
t_{width}	The time that SW1 is opened to disconnect the integrators from the signal inputs at the time of reset. This can be beneficial to reduce the perturbation from the reset switching transient charging the cable capacitance. On the PSI Diagnostic you set SW1 time (Back), so t_{width} = [SW1 time (Back)] – [SW1 time (Front)].

Figure 27 shows examples of real internal waveforms for a setup with t_{per} = 100 µsec, four subsamples to give t_{sub} = 25 µsec, t_{reset} = 20 µsec, t_{settle} = 25 µsec, t_{setup} = 8 µsec. Note the five pairs of ADC conversions (yellow trace), corresponding to four subsample measurements plus the initial zero, for the two channels (blue and pink traces). The real integrator outputs are negative-going signals as shown, whereas they are shown as positive going in the schematic figures elsewhere in this manual for convenience.

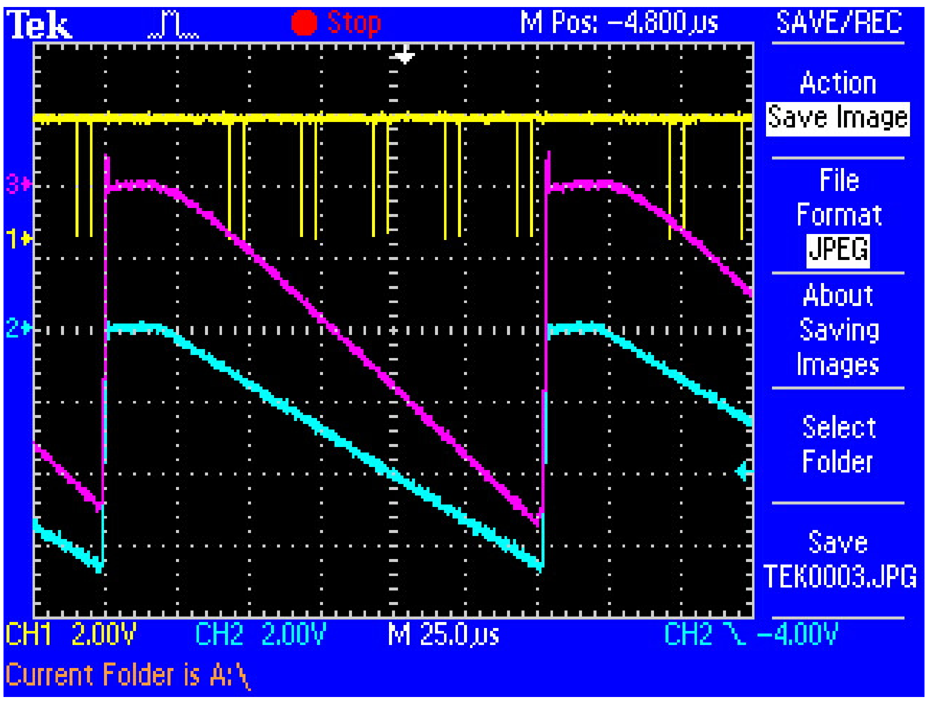


Figure 27. Example measured internal waveforms.

The frequency at which new complete integration readings are generated is

$$F_{update} = \frac{1}{(t_{per} + t_{reset} + t_{settle} + t_{setup})}$$

The live time proportion is given by

$$\frac{t_{per}}{(t_{per} + t_{reset} + t_{settle} + t_{setup})}$$

The default reset, settle and setup times for the standard and optional feedback capacitor choices are:

C_{fb}	t_{setup}	t_{reset}	t_{settle}	t_{width}	t_{offset}
10 pF	8 µsec	20 µsec	25 µsec	5 µsec	-1 µsec
1000 pF	8 µsec	20 µsec	25 µsec	5 µsec	-1 µsec

If the livetime proportion is more important than absolute accuracy and precision in your application, then it may be beneficial to reduce the settle, reset and settle times below their nominal values, until you notice an unacceptable degradation in accuracy and precision.

14.6 Continuous Current or Charge Measurement

The I200 returns charge readings to its host plus the time over which the charge was integrated. The data can thus be presented as charge or current. By continuous repetition of the measurement the I200 can make a continuous reading of the current or charge on its inputs. In this mode it behaves like a sensitive current to voltage converter. The input current can be positive or negative. A positive reading represents conventional current flowing into the I200. A negative reading represents conventional current flowing out of the I200.

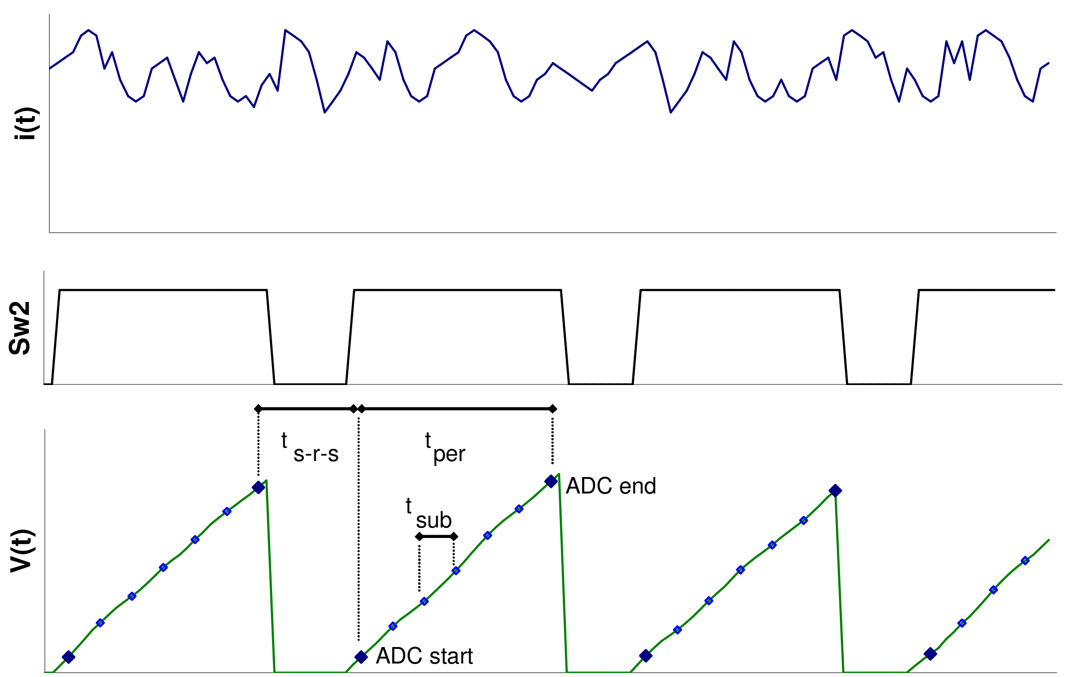


Figure 28. Timing diagram for continuous current monitoring. The deadtime for setup, reset and settle (t_{s-r-s}) is shown relatively large for clarity.

Repeated integrations of the specified period t_{per} are made. Each integration yields start and end ADC values, plus interim charge values from any sub-integration sampling that has been requested. The PSI Diagnostic host allows you to record data directly as charge. Figure 29

shows an example of this, for a case with five 20 µsec subsamples in each of three 100 µsec integrations., while measuring the 500 nA internal calibration source. Note that the charge accumulates during each integration, but is reset for each new integration, as you would expect from the operation of the integrators.

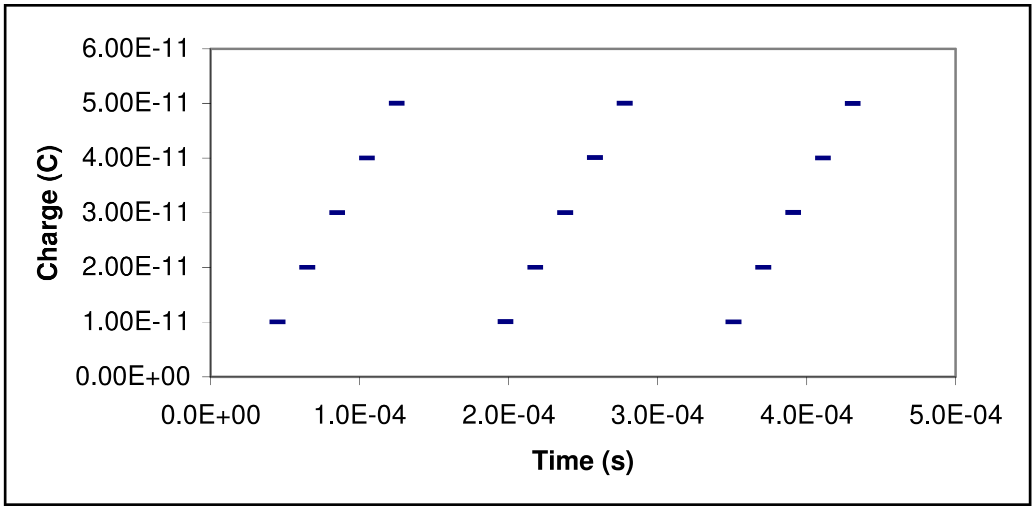


Figure 29. Readings recorded as charge.

Conversion to current is simply a matter of dividing by the appropriate time interval, t. The reported current value for any subsample or complete integration period is

$$i_{meas} = \frac{k(ADC_{end} - ADC_{start})}{t}$$

where k (coulomb bit^{-1}) includes the stored calibration factor for that channel with the feedback capacitor in use. Figure 30 shows the result of converting the data of figure 29 to current.

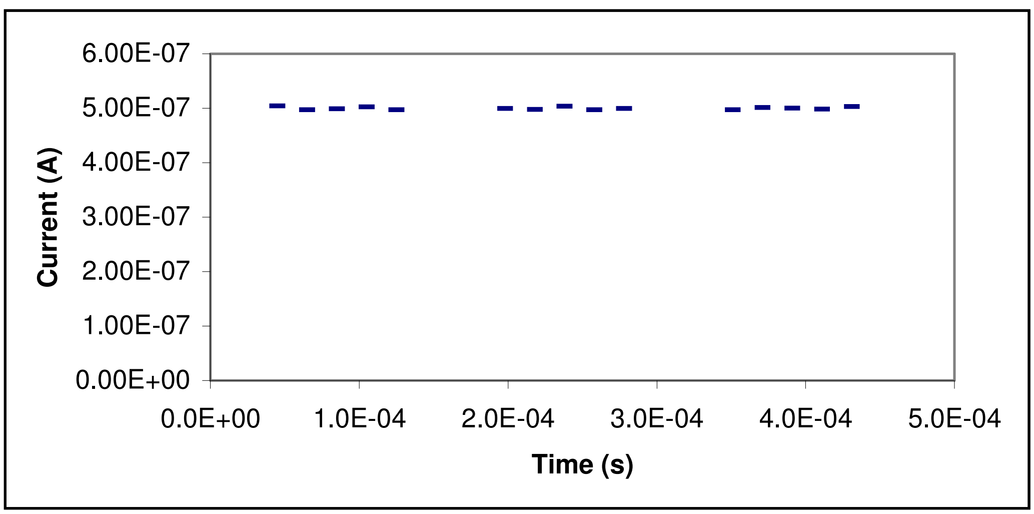


Figure 30. Readings recorded as current.

The deadtime (composed of setup, reset and settle time components) while the integrators are being reset does not generally affect the integrity of a current measurement. The only exception would be a case where a significant frequency component of the signal happened to coincide closely with the integration cycle. This can be checked and avoided if necessary by altering the integration period.

14.7 Charge Accumulation Modes

Applications such as radiation dosimetry often require the total charge to be accumulated, so that a process can be halted when a particular value is reached. When charge accumulation is turned on, the I200 keeps running total of the accumulated charge across all the integrations since the last initialize. If sub-samples have been specified, these are used as interim values to be added temporarily to the accumulating total. They are superseded by subsequent sub-samples in the same integration period up until the final sample which is logged permanently to the total.

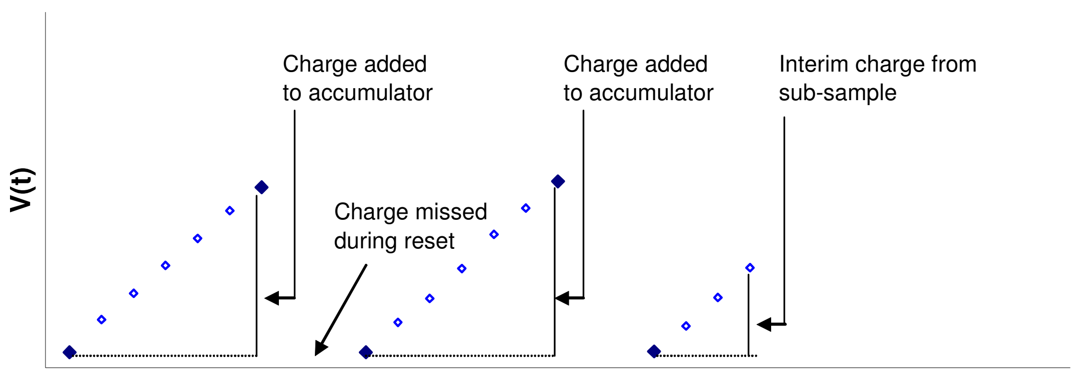


Figure 31. Illustration of integrator voltage at ADC sampling points during charge accumulation. The reset periods are shown relatively large.

There are three alternative means of dealing with the charge that is missed during the integrator resets. These are no correction, interpolation, and no-lost charge.

14.7.1 No reset time correction

Simply ignoring the loss during the deadtime can be appropriate when the deadtime is a very small fraction of the total time. For example, with one second integrations and a 10pF feedback capacitor, the percentage deadtime is about 0.003% of the total time, which is negligible.

14.7.2 Reset time interpolation

The I200 assumes that the measured charge in the last integration period may be pro-rata extended over the total cycle (t_{int} + t_{setup} + t_{reset} + t_{settle}). The charge added to the accumulator for each integration cycle is thus

$$q = i_{meas}(t_{per} + t_{setup} + t_{reset} + t_{settle}) = \frac{k(ADC_{end} - ADC_{start})}{t_{per}}.(t_{per} + t_{setup} + t_{reset} + t_{settle})$$

14.7.3 Lossless accumulation technique

In critical dosimetry applications it may be important to know the total accumulated charge over a period of time, without making any assumption about what happened during the integrator resets. The I200 can achieve this for signal sources that can be modeled as a capacitance in parallel with a very high resistance. This is a good model for ionization chambers, isolated electrodes that collect charged particles, and photodiodes.

The method is to use the inherent capacitance of the sensor, C_s, to capture the charge during the integrator reset cycle, then to transfer this charge onto the feedback capacitor at the start of the next integration. The switching sequence is illustrated in figure 32.

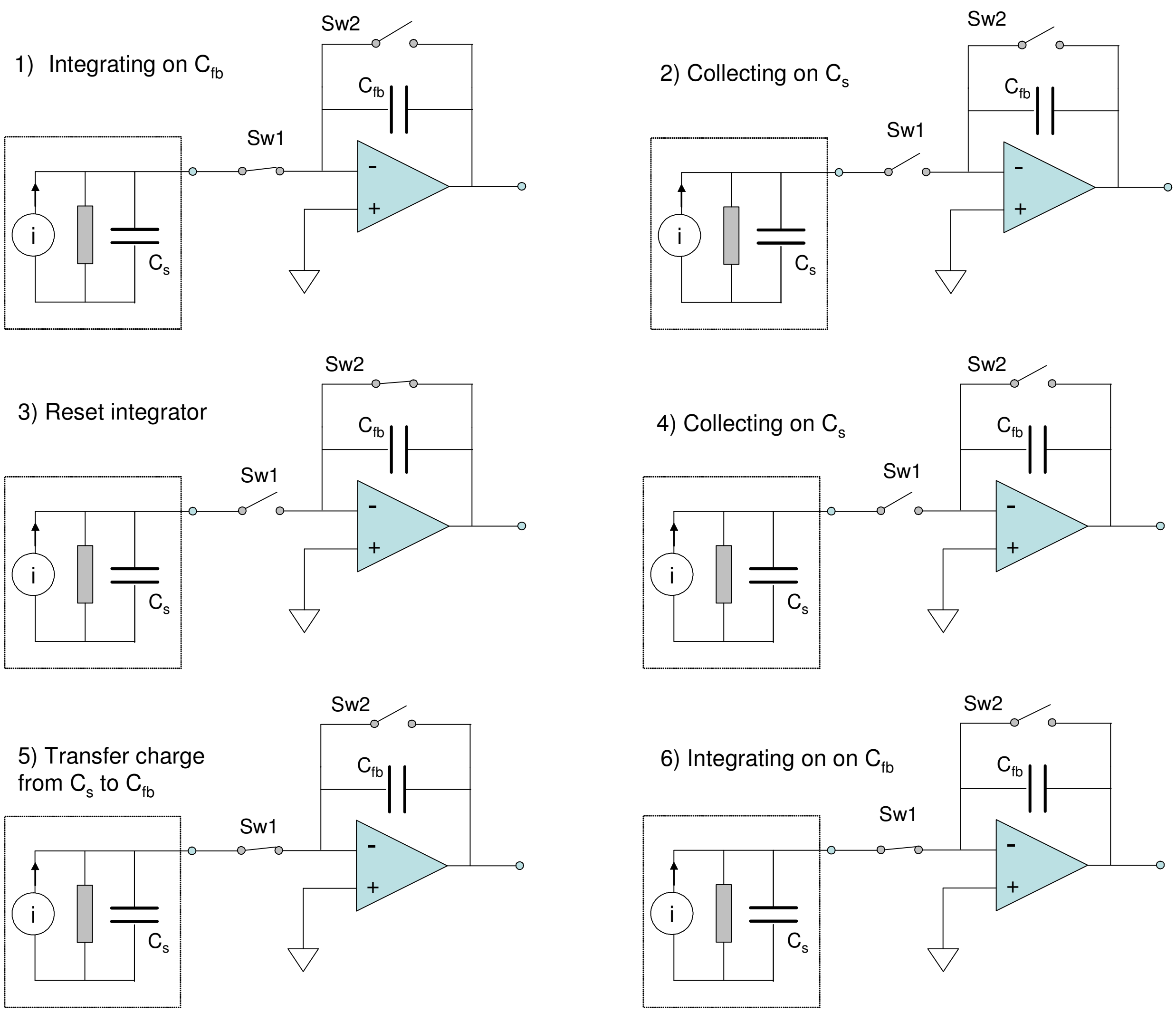


Figure 32. Switching sequence for the no-lost charge method.

Consider the integrator working normally, with charge accumulating on C_{fb}, and thus voltage increasing at the output (1). The mode 2 no charge loss reset cycle starts by opening the input switch Sw1 (2). If the load parallel resistance is high, the only place that the source current can now go is to build up charge on C_s. The integrator is now reset (3) by closing Sw1; charge continues to accumulate on C_s (4). When Sw1 closes again, the accumulated charge transfers quickly to C_{fb}. This is because the effective input capacitance of the integrator is much greater that C_s due to the amplifier action (5). The integrator output voltage jumps upward as a result of the transferred charge. Assuming lossless transfer, the net result is to extend the integration time over the complete reset cycle, so that all of the incoming charge is measured. The integration now proceeds normally again (6).

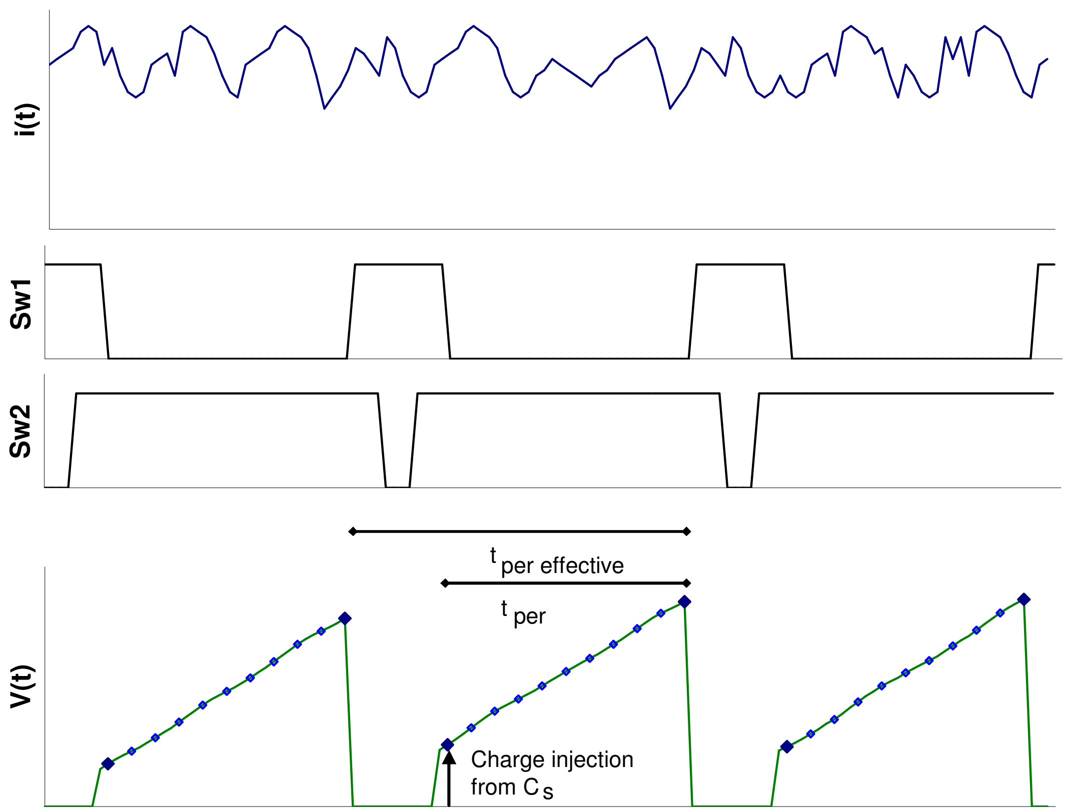


Figure 33. No lost charge timing diagram.

14.8 Time Resolved Measurements

14.8.1 Standard Mode and FastMode

The I200 can operate in two data transfer modes according to the type of host system it is communicating with.

Standard mode
The I200 generates readings at the rate dictated by the integration time, subsample count and reset parameters. The host system collects these readings, converted to amps or coulombs by the I200, at the rate allowed by the host software and the communications link. Any readings which are not collected before the next reading overwrites them are lost.

Standard mode communications can be by ASCII or binary messages, with binary more efficient and thus faster. The readings are translated to using the stored calibration.

FastMode
FastMode is only available in combination with the Pyramid Technical Consultants, Inc. A500 real-time controller. It is automatically selected with the first initiate command for all running modes *except* all accumulation modes, gated trigger mode, and message trigger mode. If you are using the PSI Diagnostic host software, there is a LED display on the Data tab which shows that FastMode is in use. FastMode permits use of integration periods and subsample periods down to 20 μsec.

FastMode communications are in the form of raw 16-bit data. The application of the calibration and translation to physical units is performed by the A500, using calibration factors uploaded from the I200.

The I200 on-board memory can store up to 768 readings. These are guaranteed to be contiguous, even at the shortest integration and subsample periods. Note that there will be deadtimes for each integrator reset, however. If you wish to capture a single shot event with no breaks in the data, then this is still possible by using multiple subsamples in a single integration which encompasses the event. Up to 256 subsamples can be used per integration. The full ADC resolution is effectively shared between the subsamples. You must also take care that the integrator does not overrange during the event.

In addition to the I200 on-board storage, the A500 can store over 1,000,000 readings. These will be contiguous if the communications between the I200 and the A500 can keep up with the data generation rate. This in turn depends upon the available bandwidth on the loop that services the I200.

14.8.2 Example of single shot time-resolved data capture at high rate

Clearly FastMode is required for the best time-resolved reading capability. It is particularly suited to capturing a sequence of readings across a single-shot event such as a short beam pulse, where an external trigger signal is available. The best way to understand this is to look at a practical example. For the example, an I200 input was driven with a pulse from a function generator with the characteristic shape shown in figure 34. This was converted to current with a peak value of 18 nA using a 10 Mohm resistor.

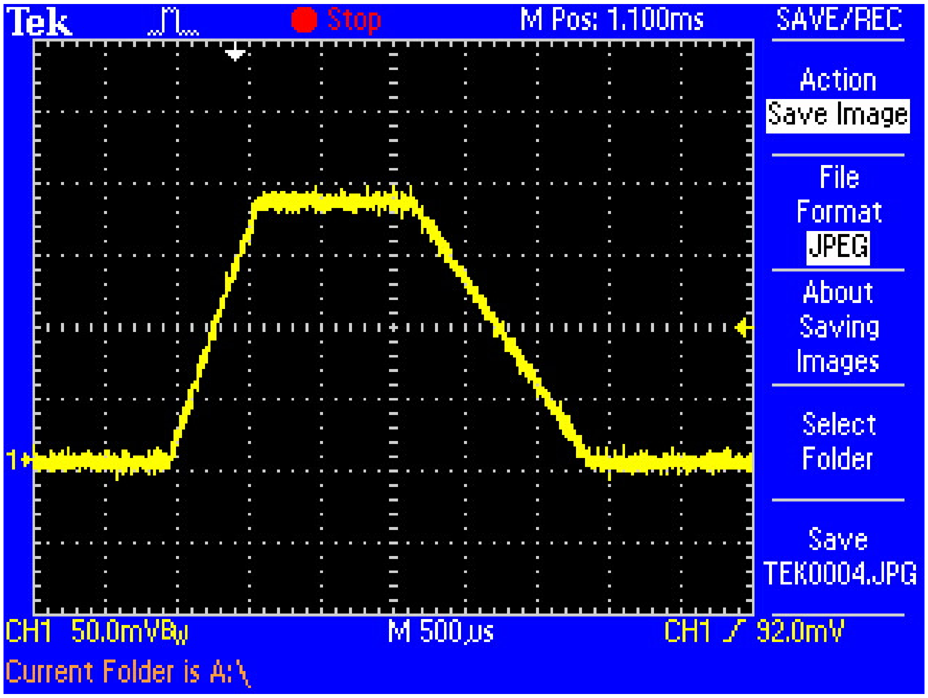


Figure 34. Pulse input used to create a one-shot current pulse signal for the I200.

In order to sample this waveform with the highest possible time resolution and no deadtime, a single integration with a large number of subsamples was used. The I200 was set to capture 250 subsamples over a 5 msec integration, and thus a subsample period of 20 µsec, using an external trigger from the signal generator. The resulting captured waveform is shown in figure 35.

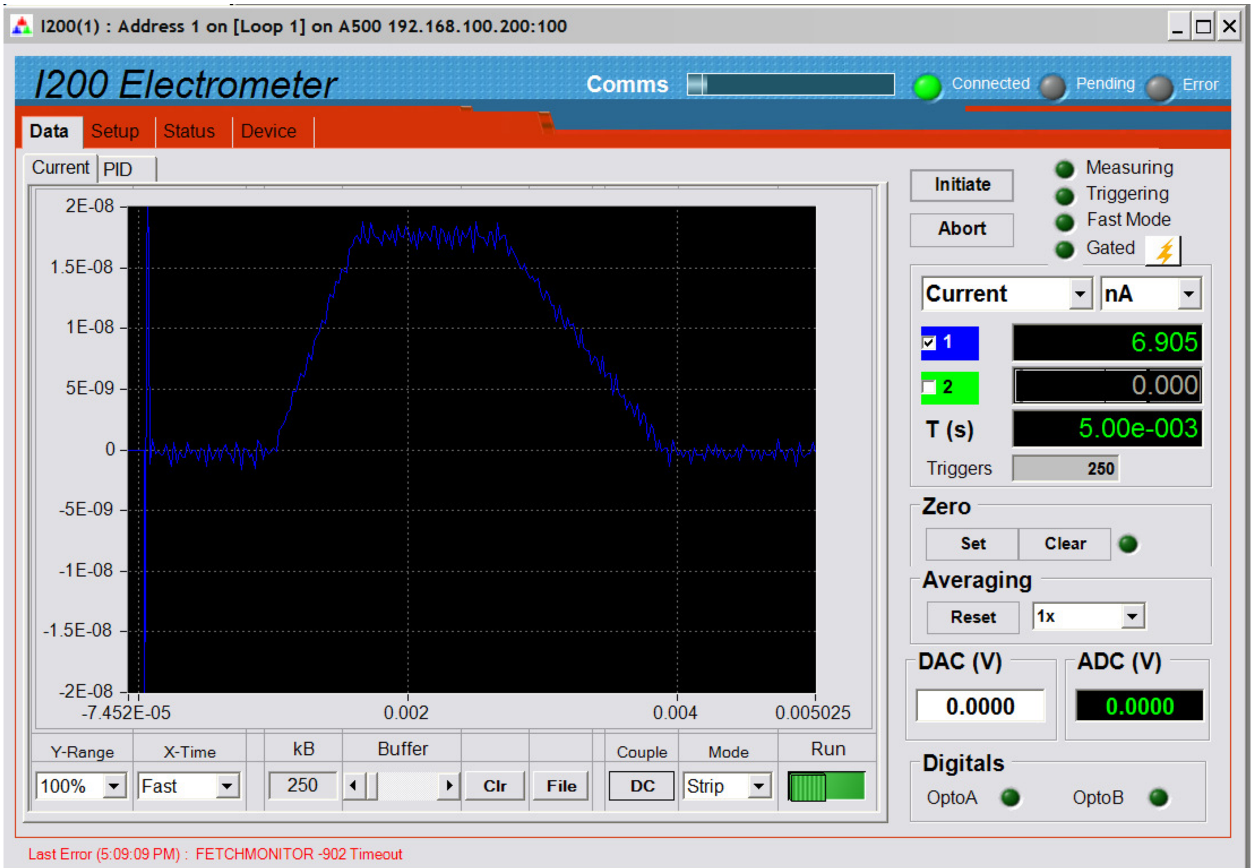


Figure 35. Example of single shot time-resolved data captured by the I200 in fast mode.

Note that the ability to take time-resolved data is limited ultimately by signal to noise ratio, and the frequency components of the noise. At short integration or sub-sample periods, lower frequency noise components are not averaged, so you may end up with nothing more than good time-resolved noise if there is insufficient signal and / or your noise levels are high.

14.9 Data Readout and Buffering

14.9.1 Data readout and buffering in ASCII mode

In ASCII mode, the ADC readings are converted to floating point numbers in coulombs by application of the calibration in the I200. The value for each channel requires 12 bytes, and the integration time and the overrange byte add to this to give a message size for reading out both channels of 37 bytes. The maximum data rate to the host is 3 Mbps via USB, and 115 kbps via RS-232, so the transmission time for the data is in the range 0.1 to several milliseconds. The data rate will generally be less than this implies, because the host must send messages on the same fiber optic channel, and there may be other devices if you are using a loop topology.

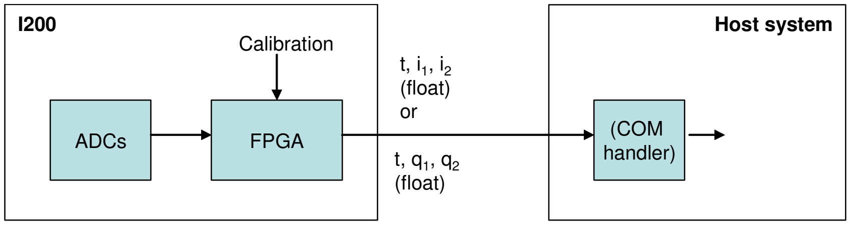


Figure 36. Dataflow in ASCII mode

If data is generated by the I200 at a higher rate than the maximum available transmission rate, then samples that cannot be transmitted are discarded. Because each 2-channel sample is given a sequential index number corresponding to each trigger, you can see if any samples have been lost by examining the data. In the basic application of monitoring a slowly varying current with random noise components, such missing data is of little consequence. However if you are attempting to capture a transient event, then this is likely to be unacceptable, and you should use a higher bandwidth communication protocol and interface.

14.9.2 Data readout and buffering in binary mode

Binary mode provides higher performance, especially when the I200 is connected to a real-time controller such as the A500. Each channel requires four bytes which represent the charge value, and the maximum communication speed using the fiber-optic loop is 10 Mbps, so data rates can be 5 to 10 times faster than the best that can be achieved in ASCII mode. Values are sent up to the host as they are generated.

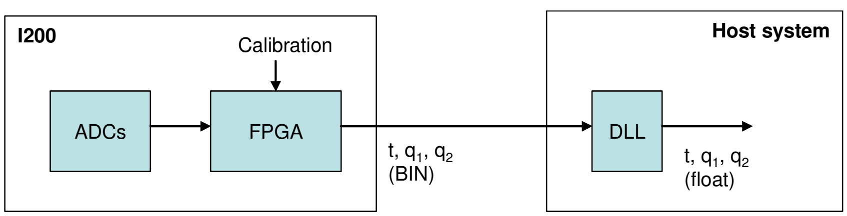


Figure 37. Dataflow in binary mode without A500.

The A500 has the capability to buffer a sequence of over a million values. Depending upon the loading of the communication channel, the integration period may be as short as 100 µsec with no lost data.

14.9.3 Data readout and buffering in FastMode

In FastMode the translation to coulombs is performed by the A500, using the calibration data uploaded from the I200. This process is transparent to the host computer. In this mode it is also possible to buffer up to 768 samples in the I200 itself, which allows contiguous sub-sampled data with periods down to 20 µsec in all circumstances. This is the highest available time resolution, and can be used. The A500 can also buffer over one million samples in its own memory, which may be contiguous data if the data transfer rate from I200 to A500 is greater than the rate at which data is generated by the I200. If the I200 is the only device running on a fiber-optic loop, then this can be achieved at 20 µsec.

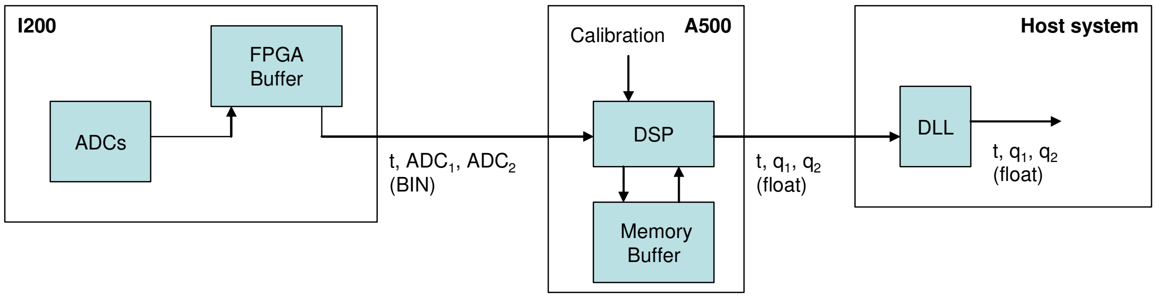


Figure 38. Dataflow in fast binary mode with A500.

14.9.4 Triggering

14.9.5 Triggering, trigger points and measurement timing

Every measurement sequence recorded by the I200 is a result of a sequence of triggers. The sequence is started either internally, or as the result of an external event. You preset all the relevant parameters such as feedback capacitor, integration period, number of sub-samples, and type and number of triggers. Then initiate the measurement. The measurements only starts however when a trigger is detected.

As an example, say that you have requested ten trigger points, four sub-samples per integration, and "ExternalStart" trigger mode, to be triggered by a high logic level on the BNC input. The initiate command primes the I200 for datas collection, but it will then wait until the trigger start event is detected. The status LED will be orange in this waiting state. When the gate input goes high, the measurement sequence will start. The status LED goes to green. Four trigger points occur in the first integration period from the four sub-samples, four in the second integration, and then the requested total of ten is reached halfway through the third integration. Measurements stop being recorded, and the status LED turns off. Note that the analog integrators continue to run even after the measurement has been completed, until you send the abort or initiate commands, or new parameters are sent. If you set the number of trigger points to infinite, measurements will continue indefinitely following the start event.

If you are in internal triggering mode, the start event is generated internally. The sequence therefore starts immediately after you send the initiate command.

The I200 keeps count of the number of trigger points, n, following the start event, and this number is used to determine the time of any measurement relative to the start of the sequence:

$$t_n = t_{settle} + n\left(\frac{t_{\text{int}}}{N_{sub}}\right) + INT\left(\frac{n}{N_{sub}} - 0.1\right)\left(t_{settle} + t_{reset} + t_{setup}\right)$$

where N_{sub} is the number of subsamples per integration. The formula simply reflects the fact that you always start with a settle time, followed by an integration with a number of sub-samples, then followed by the reset sequence.

14.9.6 Trigger sources

There are several potential trigger sources and modes. The gate polarity (ie whether rising or falling edges cause the stated responses) depends on the gate polarity parameter.

Internal	Auto-run. The start event is generated internally by the I200 once the "initiate" message is received. Readings continue until the defined number of trigger points is reached, or the "abort" message is received.
External Start	A rising (falling) edge on the gate input starts a predefined acquisition sequence. Readings continue until the defined number of trigger points is reached, or the "abort" message is received.

External Start-Stop	A rising (falling) edge on the gate input starts a predefined acquisition sequence. Readings continue until either the programmed number of integrations is complete, or the gate input falls (rises) again, in which case the sequence terminates after the sub-sample in progress. Readings continue until the defined number of triggers is reached, or the "abort" message is received.
External Gated	(no longer supported)
Message	A special one-byte message on the communication link triggers the predefined acquisition sequence. Readings continue until the defined number of triggers is reached, or the "abort" message is received. This trigger mode is only supported via the RS-232 and USB ports, or via the A200 loop controller. It is not supported through the A500 or A300 loop controllers.
ExternalStartHold	A rising (falling) level on the gate input causes the first integration of the predefined sequence. Integrations continue if the gate input stays high (low). After the gate falling (rising) edge, the integrations stop after the one in progress completes. The I200 then waits in reset for the next high (low) to cause the second integration. This process continues until the defined number of triggers is reached, or the "abort" message is received.

In all cases you can select infinite triggers and the acquisitions will continue indefinitely until you send the abort command or reset the I200.

The external and gated modes require a physical signal via the gate input BNC or the gate input fiber-optic receiver. They are most appropriate when you require the minimum (sub-microsecond) and most consistent delay between the trigger and the start of integration. The selection of the active trigger input is via a software command; the default is the BNC. The sense of the logic is a software configurable parameter.

The BNC input requires a TTL level, and presents a TTL gate impedance. To avoid spurious signals due to noise, we recommend that you fit a 50 ohm terminator to this input if you are not using it. If your trigger source is able to drive a 50 ohm load, we also recommend this termination if you are using the input to guarantee clean trigger edges.

The fiber-optic input requires an on/off light, 640 nm nominal wavelength. If you do not intend to use the optical trigger input, you should ensure it is not selected to avoid accidental triggers from ambient light, or fit a blanking plug.

Message triggering provides similar performance to the external modes, but with slightly greater delay. In looped systems, the loop controller knows the position of each device in the loop, and arranges for each device on the loop responding to the trigger to delay its response according to its position in the loop, so that all devices start their acquisitions at the same time.

14.9.7 Illustrations of external triggers

Figure 39 is a schematic example showing an external start trigger of a sequence of seven integrations. Each integration includes three sub-samples, for a total trigger point count of 21. Data is of course gathered on each of the two channels. A similar sequence could be started by a message trigger.

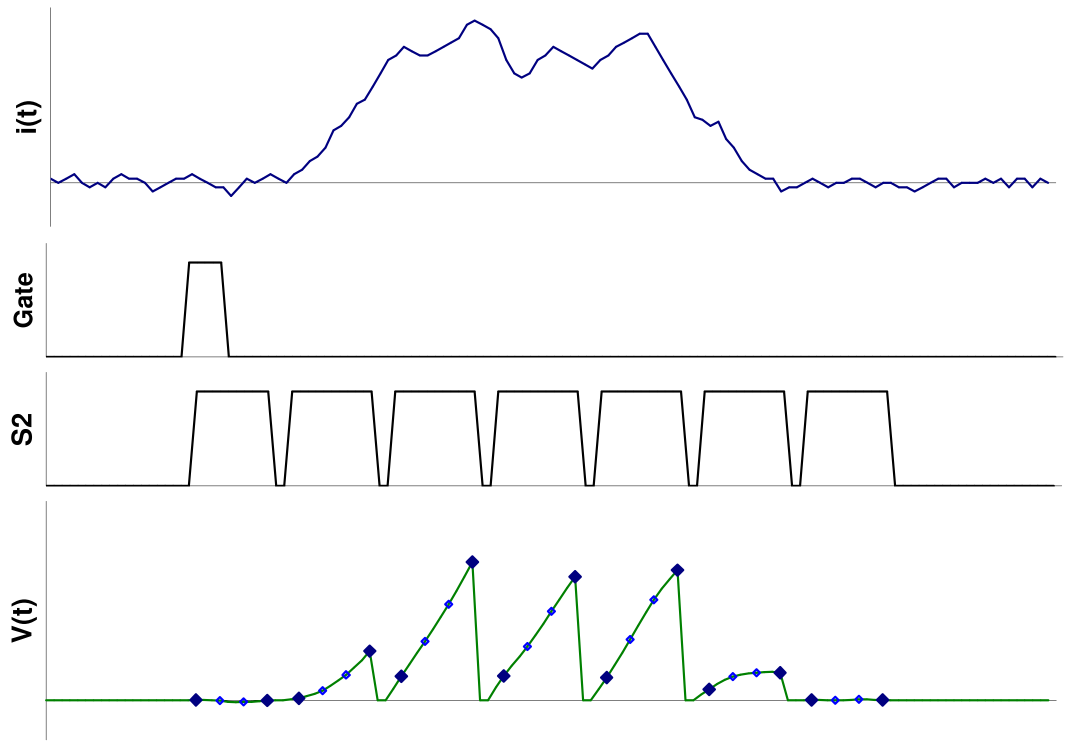


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Figure 39. Example of an "external start" triggered measurement sequence started by a rising edge

Figure 40 shows an External Start-Stop trigger example. The sequence starts on the rising edge as in the previous example. However in this case the I200 is also sensitive to the falling edge. When the gate line falls again, the sequence terminates after the acquisition in progress. The external signal that starts the measurement sequence can be also be sent over the communications channel, as an alternative to making a hardware connection to the gate input connector.

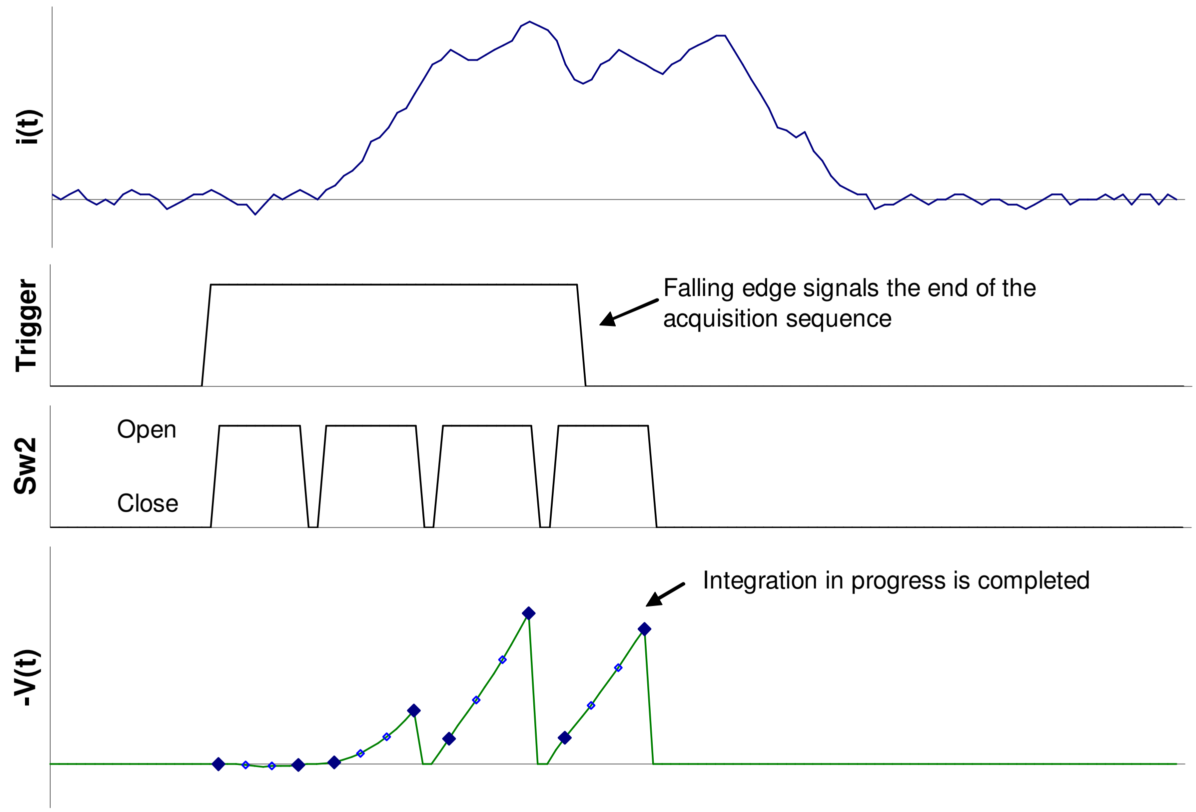


Figure 40. Example of an "external start/stop" triggered measurement sequence started by a rising edge and ended by a falling edge.

Figure 41 shows an External Start-Hold trigger example. The gate has to go high to release the first integration. If the gate is low again at the end of that integration, the integrators remain in hold until the gate goes high again. In this manner the external trigger signal can directly control when the integrations occur. If the gate is still high when an integration ends, then the next will start immediately. The whole process ends either when the trigger count is reached, or the host aborts the measurement.

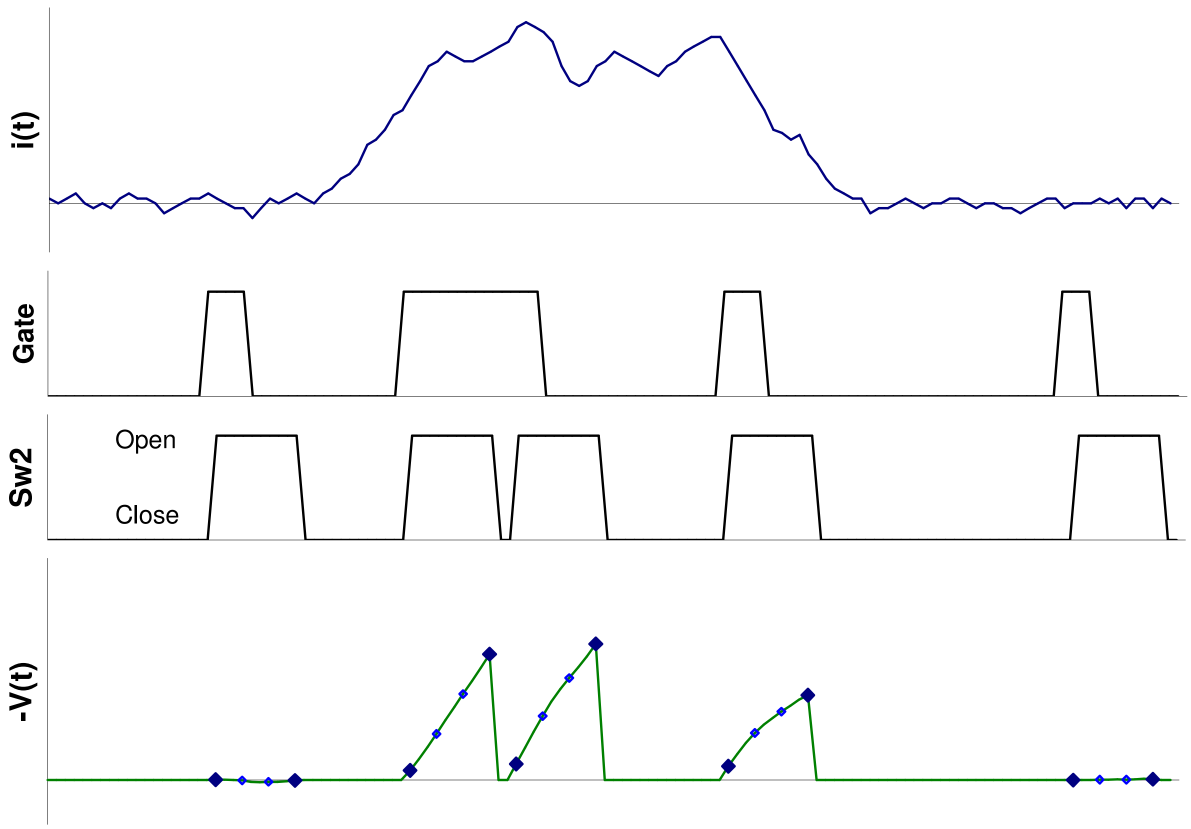


Figure 41. Example of an "external start/hold" triggered measurement sequence.

15 Calibration and background offset current correction

Taking accurate current or charge measurements with the I200 require accurate gain factors, k, for each channel and consideration of the background offset current.

15.1 Background offsets

Consider an integration cycle as shown in figure 42. The voltage presented to the (ideal) ADC comprises the integrated signal, $V_{signal\_current}$, the integral of any net background offset current, $V_{bdg\_current}$, and a voltage pedestal, V_{offset}, due to amplifier offsets and the offset of the ADC itself. In practice these unwanted offsets will be much smaller than the signal, and may be negative or positive relative to the signal, but they must nevertheless be managed correctly to get maximum accuracy at the lowest currents and charges.

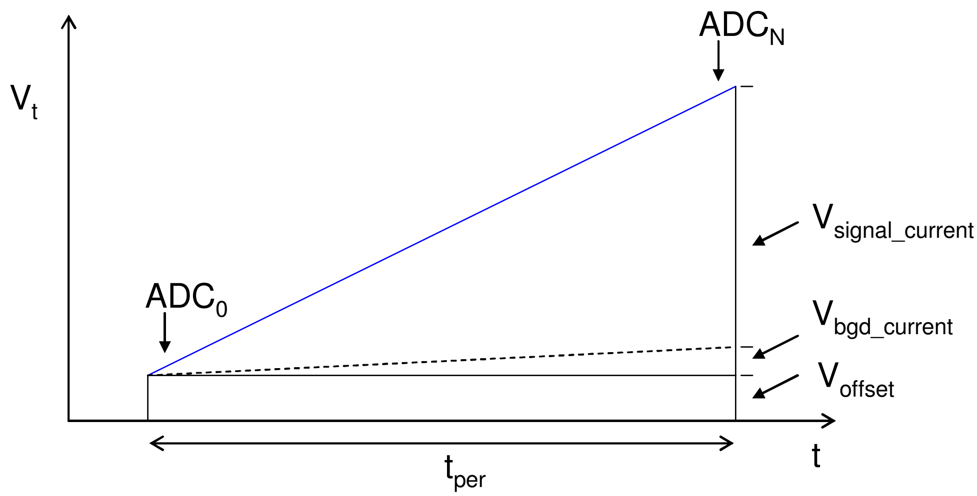


Figure 42. An integration showing signal and noise contributions to the final output.

V_{offset} is eliminated automatically by the operation of the I200, because the charge is measured as $k(ADC_N - ADC_0)$, so the offset cancels.

Background current is not eliminated automatically, because it is indistinguishable from signal current at any moment in time. The I200 internal background current is small (pA level) and stable. The background from the external circuit will generally be higher, but depends greatly on the particular sensor or transducer.

Depending upon your measurement needs, it may be appropriate to subtract the total background current if it is significant relative to the signal, and relatively stable. You should be careful of changes to the background which would render any such correction invalid, however. This could be due to changes in temperature or electrical noise.

Background nulling can be automated in the host software. The background should be measured with a long integration period, sufficient to get an accurate value, and with no true signal present, only the background current. The resulting background current values, i_{bgd}, for each channel can

be subtracted from subsequent current readings, either manually or in host software. In charge measurement modes, subtract (i_{bdg} x t_{per}).

15.2 Gain calibration

The calibration gain factors convert charge into ADC output, and thus are the composite of the feedback capacitor size, buffer amplifier gain and ADC gain. The I200 calibrates itself automatically on all channels by switching on the internal 500.00 nA current source and making measurements with known integration period.

IMPORTANT: There must be no signal current flowing into the inputs when the calibration is taking place, because it will add to the calibration current and give an incorrect result. This incorrect calibration would not be detectable by checking the internal calibration source readback, but only by measuring a known independent current source.
Because background offset current can affect the gain calibration process itself, the I200 also makes a background measurement as part of the calibration cycle. The measured background ADC difference is subtracted from the ADC difference measured with the calibration source on to get the net value that is equated to 500 nA.

The calibration factors are stored in the I200 in EEPROM when a “save calibration” command is issued. They are then loaded automatically on power-up. The host computer can upload them for use in binary communication modes. If there is no calibration available, the I200 will use a nominal calibration and the measurements will be of reduced accuracy.

16 High Voltage Supply

16.1 Setting the high voltage

The range and polarity of the high voltage supply is fixed and must be specified at time of purchase. Units may be returned to the factory to alter the high voltage modules if necessary. The set value can be adjusted at any time, independent of what measurements are in progress. Any valid setpoint above zero volts enables the supply. The HV on LED illuminates when the supply is enabled.

Each supply is limited by a software high voltage limit, which is password protected and stored in EEPROM in the I200. The I200 will reject any attempts to set the voltage higher than the limit. This allows sensitive detector systems, or experiments which may be damaged by excessive voltage, to be protected.

CAUTION

Note that the HV modules are not designed to operate below 10% of their maximum rating. They will regulate at lower voltages than this, but at startup you may see the voltage overshoot considerably before it settles to the setpoint over a period of a few seconds. This happens irrespective of any high voltage limit you have set. Always specify an HV module option that matches the requirements of your sensor system.

The maximum current compliance of the high voltage power supplies depends upon the output voltage. At low outputs, the compliance of the 1000V high voltage supplies, for example, can be represented as the current that the voltage would cause to flow in a resistor of about 300 kohm. Thus up to 100 µA is available at 30 V output, 200 µA at 60 V output and so on. At higher outputs it is limited to 1 mA maximum. HV modules with lower voltage rating can be specified at the time of order, which provide correspondingly greater current compliance.

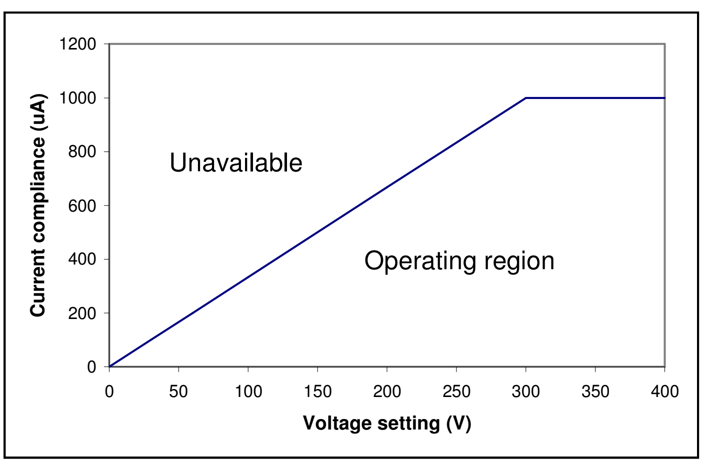


Figure 43. Current compliance of the 1000V high voltage supplies.

Positive supplies source conventional current, and negative supplies sink conventional current. A 25 Mohm bleed resistor fixed load is connected to each high voltage supply output which drains 40 µA at maximum voltage from the 1000V supply. Transorb protection devices prevent the absolute value voltage at the output going more than 80 V above the maximum rating. However these devices are not designed to pass large currents indefinitely, so you should be careful not to overdrive the outputs with other power supplies or with charged particle beam strike currents.

The output voltage is monitored by a 10 bit ADC, and the value can be displayed by the host software. The monitor value is not used for control or feedback purposes. It is of relatively low accuracy, and is only intended for confirmation that HV output is being generated. You can tell if the voltage is being pulled down by excessive current drain by watching for relative changes.

CAUTION
Do not connect external power supplies to the I200 external high voltage output that will drive the built-in supply away from the voltages it is trying to regulate, or you may cause damage to the I200.

CAUTION
Do not connect the I200 signal inputs, or the external high voltage output, to electrodes in a system that will be subject to direct strike by high energy, high current charged particle beams that will drive the built-in supply above the voltage it is trying to regulate, or you may cause damage to the I200.

16.2 High voltage options

The range and polarity of the high voltage supplies is fixed and must be specified at time of purchase. The following HV options are available:

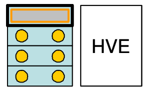
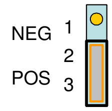
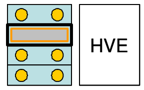
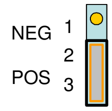
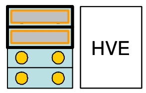
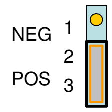
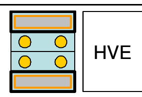
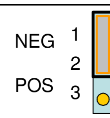
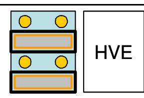
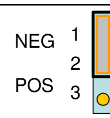
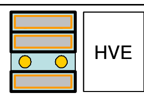
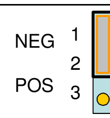
I200 option	Maximum voltage	Current rating
-XP10	+1000	1 mA
-XP5	+500	2 mA
-XP2	+200	5 mA
-XN10	-1000	1 mA
-XN5	-500	2 mA
-XN2	-200	5 mA

Units may be returned to the factory to alter the high voltage modules. It not recommended that users change the high voltage supply module.

CAUTION

Incorrect jumper setting can result in the incorrect output voltage and no output voltage feedback.

The necessary configuration details are given here for reference.

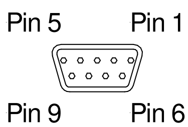
HV Module	JPR 2 setting	JPR 4 setting
+1000 V		
+500 V		
+200 V		
-1000 V		
-500 V		
-200 V		

17 Connectors

17.1 Front panel connectors

17.1.1 Auxiliary I/O

Nine pin Dsub female.

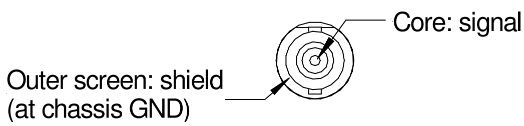


(External view on connector / solder side of mating plug)

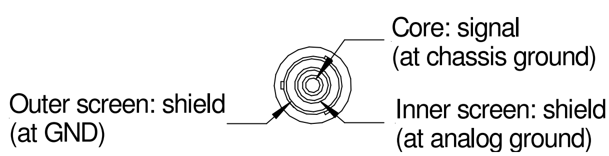
1	Analog Gnd	6	Analog output (Process control DAC)
2	Analog Gnd	7	Analog input
3	+24 VDC out	8	PSU Gnd (24 V rtn)
4	Opto common	9	Opto in B
5	Opto in A		

17.1.2 Signal inputs

Coaxial BNC socket, two (channel 1 and channel 2). To mate with a standard BNC plug.



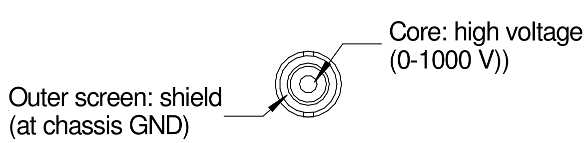
Triaxial female connectors are available as an option, two (channel 1 and channel 2). To mate with three-lug standard triaxial connector such as Trompeter PL74-7. To adapt to BNC, use adaptor Trompeter ADBJ20-E2-PL75.



Two lug triaxial connectors are available to special order as a further option.

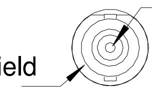
17.1.3 Auxiliary HV out

SHV male. To mate with standard SHV connector such as Radiall R317 005.



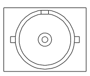
17.1.4 TTL gate input

BNC socket (female) for gate and trigger inputs. To mate with standard signal BNC.



17.1.5 Optical gate input

ST socket bayonet female for gate and trigger inputs. To mate with ST terminated fiber optic.



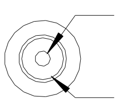
17.1.6 Ground lug

M3 threaded stud. To mate with M3 ring lug.

17.2 Rear panel connectors

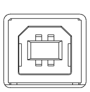
17.2.1 Power input

2.1 mm threaded jack. To mate with Switchcraft S761K or equivalent



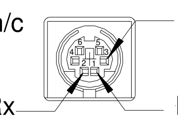
17.2.2 USB communications

USB type B female.



17.2.3 RS-232 communications

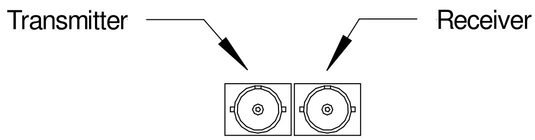
Six pin mini-DIN socket (PS/2 mouse/keyboard type).



(External view on connector / solder side of mating plug)

17.2.4 Fiber-optic communications

ST bayonet. To mate with ST male terminated fiber optic cable. Transmitter is light gray, receiver id dark gray.



18 Controls and Indicators

18.1 Front panel controls

None.

18.2 Rear panel controls

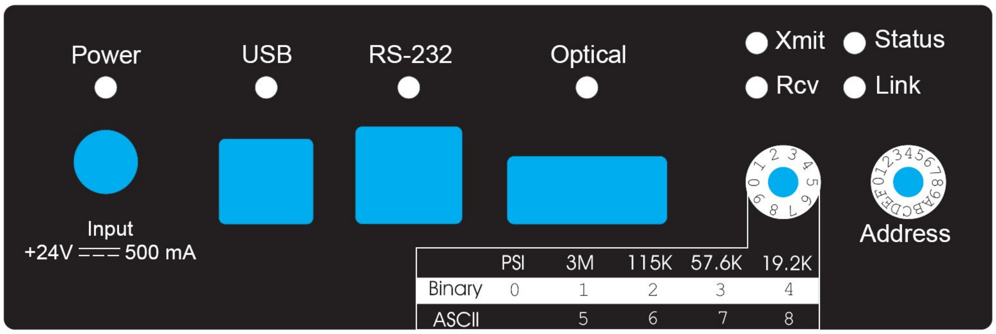


Figure 44. Rear panel showing controls and indicators

18.2.1 Mode switch

10 position rotary switch setting communications mode. Binary protocols are used for highest data rates by the PSI Diagnostic program, and other suitable host systems. The fiber optic link can run up to 10Mbps, the USB up to 3 Mbps and the RS-232 up to 115.2 kbps. The ASCII protocol is provided for ease of connection to existing systems and simple terminal programs.

Setting	Function
0	9 bit binary, 10 Mbps
1	8 bit binary, 3 Mbps
2	8 bit binary, 115.2 kbps
3	8 bit binary, 57.6 kbps
4	8 bit binary, 19.2 kbps
5	ASCII, 3 Mbps
6	ASCII, 115.2 kbps
7	ASCII, 57.6 kbps
8	ASCII, 19.2 kbps
9	(Reserved)

The switch setting works in conjunction with the connector sensor (see section 19).

18.2.2 Address switch

16 position rotary switch setting device address. Choice of address is arbitrary, but each device in a fiber-optic loop system must have a unique address.

Setting	Function
0	(Reserved to loop controller)
1-15	Available address settings.

18.3 Front panel indicators

18.3.1 HV on

Red LED. The HV supply is enabled.

18.4 Rear panel indicators

18.4.1 +24V

Green LED. +24VDC power is present, 5V DC-DC converter is running.

18.4.2 USB

Green LED. USB communication is active.

18.4.3 RS-232

Green LED. RS-232 communication is active.

18.4.4 Optical

Green LED. Fiber-optic communication is active.

18.4.5 Xmit

Green LED. Data being transmitted from outgoing message buffer.

18.4.6 Rcv

Green LED. Data being received into the incoming message buffer.

18.4.7 Status

Red/Green LED. This LED indicates a variety of internal states, as follows:

Alternating red/orange/green/off	Unit powering up
Off	Unit idle (not measuring)
Orange	Waiting for trigger; or resetting integrators
Green	Integrating
Red	Error
Alternating green/orange	Downloading program from host

18.4.8 Link

Red/Green LED. This LED indicates a variety of communication states, as follows:

Alternating red/orange/green/off	Unit powering up
Off	No connection since last power-up.
Alternating green/off	Unconnected
Alternating orange/off	Unconnected; unit has gone to the safe state.
Green	Connected
Red	Fatal communications error
Fast alternating green/orange	Boot state (waiting start command or code download)

19 Communications Interfaces

The I200 is provided with three hardware communications interfaces, RS-232, USB and fiber-optic. The RS-232 and USB interfaces are intended for simple direct connection to PCs, with no other equipment necessary. The fiber-optic interface provides greater speed, excellent noise immunity, and allows multiple devices to be connected in a looped topology. It requires a fiber-optic adaptor or loop controller device to connect to the host computer. The fiber-optic interface is well-suited to large systems and experiments.

Only one interface is in use at any time. Selection of the active interface is according to the cables that are connected.

Cable connected			Interface selected
USB	RS-232	None	
x			USB
x	x		USB
	x		RS-232
		x	Fiber-optic

Interface speed and protocol is selected by the mode switch. The fiber optic interface can run up to 10 Mbps, and the RS-232 up to 115.2 kbps. The USB port always runs at 3 Mbps, irrespective of the mode switch position. The following table summarizes the interface selection and protocol that is active for all possible connector and mode switch configurations. The most common selections are shown in bold.

Cable connected			Interface selected	Protocol selected by mode switch setting									
USB	RS-232	None		0	1	2	3	4	5	6	7	8	9
x			USB	BIN 8 3M	BIN 8 3M	BIN 8 3M	BIN 8 3M	BIN 8 3M	ASC 8 3M	ASC 8 3M	ASC 8 3M	ASC 8 3M	??
x	x		USB	BIN 8 3M	BIN 8 3M	BIN 8 3M	BIN 8 3M	BIN 8 3M	ASC 8 3M	ASC 8 3M	ASC 8 3M	ASC 8 3M	??
	x		RS-232	??	??	BIN 8 115k	BIN 8 57.6k	BIN 8 19.2k	ASC 8 115k	ASC 8 115k	ASC 8 57.6k	ASC 8 19.2k	??
		x	Fiber-optic	BIN 9 10M	BIN 8 3M	BIN 8 115k	BIN 8 57.6k	BIN 8 19.2k	ASC 8 115k	ASC 8 115k	ASC 8 57.6k	ASC 8 19.2k	??

BIN 8: 8-bit nibble-oriented binary

BIN 9: 9-bit full binary

ASC 8:8-bit ASCII, SCPI message format

20 Communications protocols

20.1 Overview

The I200 supports three types of communication protocol, selected according to the setting of the mode switch:

a) An eight bit ASCII protocol, messages compliant with SCPI. The low seven bits are used to encode the ASCII character. The eighth bit is only set for synchronization when the <ACK>, <BELL>, <CR>, <LF>, and <ESC> characters are transmitted.

b) An eight bit binary protocol. The first and last bytes of the entire command or reply have the eighth bit set and contain the address. All other bytes in the messages are broken into two bytes, encoded into the low nibble (4 bits), thus never having the top bit set.

c) A nine bit binary protocol. Synchronization is done with the ninth bit. The first and last byte of each message have the ninth bit set and contain the address, and all other bytes are unmodified binary (with the ninth bit clear).

ASCII messaging is provided for users who wish to use existing host software systems that provide convenient support for ASCII communications. All the capabilities of the I200 are available through a familiar virtual instrument model and message structure. A simple terminal program such as Windows Hyperterminal is sufficient to establish communication with the device. It is possible to communicate with multiple devices at different addresses on the same channel by selecting a particular address to be the listener device at any time.

The binary messaging is more efficient in its use of communications bandwidth. It is fully deterministic with embedded addressing in the messages and immediate responses, including error reports, from the devices. Pyramid provides software drivers and diagnostic host programs for users who wish to use binary communication protocols. Eight bit binary is primarily intended for direct host to device communication, for example via RS-2332 or USB links. Nine bit binary is reserved for the 10 Mbit/s fiber-optic channel, and is highly recommended for larger systems with multiple addressable devices in a loop.

20.2 ASCII Protocol - SCPI

Standard Commands for Programmable Instruments (SCPI) is an extension of the IEEE 488.2 standard. This was originally developed by Hewlett-Packard for the HP-IB (later GP-IB) interface before being adopted by the IEEE, and is widely used by manufacturers of measurement equipment. The I200 implements the 1999.0 revision of SCPI (© 1999 SCPI Consortium).

20.2.1 Messages

The first bit of every eight bit group in a message is the start bit, followed by seven bits encoding a character from the ASCII character set.

A full command from the host to the I200 comprises as many ASCII characters as needed to form the message, terminated by the LF (0x0A) character. The I200 will not start to process a command until the 0x0A character is received. The list of valid commands is listed in the next section. If the communications is being handled in a terminal session, the terminal program should send CR (0x0d) before the LF to get a legible display. The CR is ignored by the command interpreter in the I200.

The I200 generates a reply to every message from the host when it is the listener. The first byte of its reply will always be a single non-printing character. The first character is ACK (0x06) when the command has been successfully executed with no errors. Responses to host commands with a '?' will then have the required data, terminated with the CR,LF sequence. If the host is not requesting data (no "?"), no other bytes will be transmitted after the ACK. If the I200 generates an error when executing the host command, it will transmit a single BELL (0x07) as its response. A computer running a terminal program will therefore "beep" when the I200 cannot execute a command, for example due to incorrect syntax. A more interactive "terminal mode" can be selected which modifies this behavior to make the I200 more user-friendly when it is being driven from a terminal program.

Device addressing is performed using the special command '#'. Addressing is only necessary for devices linked by a fiber-optic loop, but a device is made the "listener" when the host sends #ADDRESS. For example, #4 will make the device with address 4 the listener. You must ensure that all devices on the same communications channel have unique addresses. All subsequent commands sent (without address) will be listened and responded to by device 4 only. The host message #? asks who the listener is. The # command can be sent as a compound message, such as #3;*IDN?.

20.2.2 Status registers

The I200 implements the IEEE 488.2 status register method. Each of the registers is masked by a corresponding enable register. It is recommended that you set all the enable registers to all 1's. The host software should use the *STB? command to watch for changes to the status of the I200, and then *ESR?, :STATus:OPERation:CONDition? or :STATus:QUESTionable:CONDition? as appropriate to recover the details from the relevant register.

You can use the I200 ASCII communications without using the status registers.

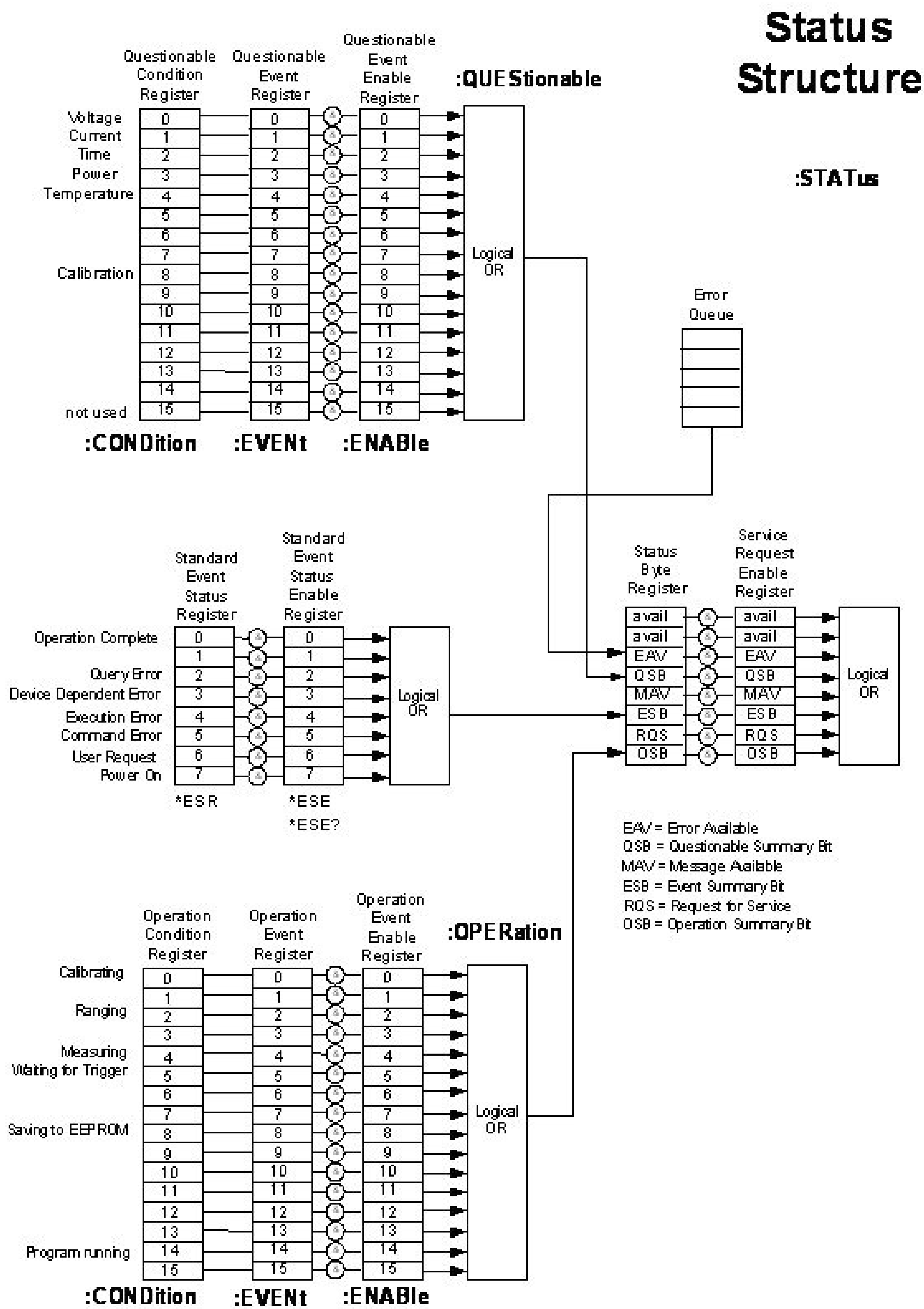


Figure 45. SCPI Status register structure

20.2.3 Host Commands

The I200 responds to the mandatory commands prescribed by SCPI and IEEE 488.2, plus specific commands as required by the operation of the device. The commands are grouped with a hierarchical structure, with the levels separated by the colon character. For example:

CONFigure:GATe:INTernal:PERiod 1e-2 5

This command configures the internal integration gate to have a length of 10 milliseconds with five sub-samples of the integrator output, after 2, 4, 6, 8, and 10 milliseconds.

SCPI provides for a long and short form for each command. The short forms are indicated by the capitalized part of the command. { } denotes a required argument, [ ] denotes an optional argument.

Some commonly-used commands are available from the root of the hierarchy, as a shortcut, as well as in their logical position in the structure. For example:
CAPacitor 1
and
CONFigure:CAPacitor 1
are equivalent ways to switch in the large feedback capacitors on the four channels.

A number of commands are password protected to reduce the chance of changing them accidentally. The commands only effective after the device has been rebooted if they have been enabled by first sending
SYSTem::PASSword 12345
Sending any other number as the argument of this command disables the protected commands again.

20.2.3.1 ADDRESSING DEVICES

SCPI does not provide specific commands for addressing multiple devices, because this was handled by hardware in the original IEEE 488.1 specification. The I200 provides a simple mechanism for making any device on the loop the listener. The device will remain the listener until another device is selected.

# {address}	// Make device address (1 to 15) the listener
#?	// Query which device is listener.

20.2.3.2 IEEE 488.2 MANDATORY COMMANDS

Commands which have a query equivalent for readback are marked with “(?)” in the following table

Parameters are generally passed to the I200 with the set version of the command, but no parameters are passed for the query version. For example,

*ESE 3 // set the Event Status Enable register to 0000011

*ESE? // query the Event Status Enable register

*CLS		Clear Status Command. Clear all event registers and the error queue
*ESE	(?)	Program (query) the state of the Event Status Enable register. 8 bits. I200 returns decimal value.
*ESR?		Standard Event Status Register Query. Query the state of the Event Status register. I200 returns decimal value.
*IDN?		Identification Query. I200 returns manufacturer, model number, serial number, firmware version
*OPC	(?)	Set (query) the Operation Complete bit in the Standard Event Status Register after all pending commands have been executed. Not currently supported.
*RST		Reset Command. Return the device to the *RST default conditions.
*SRE	(?)	Program (query) the Service Request Enable register. Not currently supported.
*STB?		Read Status Byte Query. Query the Status Byte Register. I200 returns decimal value.
*TST?		Self-Test Query. Perform a checksum test on ROM and return the result. I200 returns <1>.
*WAI		Wait-to-Continue Command. Wait until all previous commands are executed. Not currently supported.

20.2.3.3 IEEE 488.2 OPTIONAL COMMANDS

*RCL					Recall instrument state from EEPROM
*SAV					Save present instrument state to EEPROM

The settings covered by *RCL and *SAV are:

SOURce
CONFig:ACCumulation
CAPacitor
PERiod
CONFig:GATe:EXTernal:POLarity
TRIGGER:SOURce
TRIGger:POInts

Note that the high voltage settings (CONFigure:HIVOltage) are NOT included.

20.2.3.4 I200 COMMANDS

READ commands force an acquisition and return the data when it completes, and therefore the data is new. FETCh commands get the most recent value in the I200 internal buffer, which may or may not be new data.

I200 set commands which have a query equivalent for readback are marked with “(?)” in the following table. Parameters are generally passed to the I200 with the set command, but no parameters are passed for the query version. For example,

CONF:GAT:INT:PER 1e-3 5 // set the integration period to 1 msec with five sub-samples

CONF:GAT:INT:PER? // query the integration period and number of subsamples

ABORt					Abort measurement
CALIBration	:GAIn [{CLEar}]			(?)	Calibrate (query) gain for each channel, or reset stored gains to nominal
	:SOURce {0|1}			(?)	Set (query) internal calibration source state, 0 = off, 1 = on
	:RCL				Recall the gains and zero offset currents from EEPROM
	:SAV				Store the gains and zero offset currents to EEPROM
CAPacitor {0|1}				(?)	Set (query) feedback capacitor for all channels; 0 = small value, 1 = large value
CONFigure	:ACCumulation {0|1|2|3}			(?)	Set (query) accumulate charge across gate resets mode, 0 = do not accumulate 1 = accumulate by interpolation 2 = accumulate by no-lost charge method 3 = accumulate without correction for deadtime during resets
	:CAPacitor {0|1}			(?)	Set (query) feedback capacitor (all inputs) 0 = small value 1 = large value
	:GATe	:EXTernal	:POLarity {0|1}	(?)	Set (query) external gate polarity (external trigger only) 0 = high active

					1 = low active
		:INTernal	:LOSSless {0|1}	(?)	Set (query) lossless integration mode, 0 = off, 1 = on
			:PERiod {<total>|AUTOscale} [{subsamp}]	(?)	Set (query) integration period in seconds or enable autoscaling, <subsamp> subsamples per period (default 1)
			:RANGe {<amps>} [{subsamp}]	(?)	Set (query) a full scale current range by adjusting integration period for the selected capacitor, <subsamp> subsamples per period (default 1)
			:RESET {<reset>} {<settle>} {<setup>}	(?)	Set (query) the reset, settle and setup times (password protected)
	:HIVOltage	:ENAble?			Query the high voltage enable state 0 = all HV off 1 = external or signal bias HV on
		:EXTernal	:MAXvalue {<volts>}	(?)	Set (query) maximum allowable external high voltage setting (password protected)
			:VOLTs {<volts>}	(?)	Set (query) the external high voltage
	:PID	:MODe {0|1|2|3|4}		(?)	(-S1 option only) Set (query) the PID mode, where 1 = I1 2 = I1+I2 3 = I1-I2 4 = I1/I2 5 = (I1-I2)/(I1+I2)
		:RATe {<per>}		(?)	(-S1 option only) Set (query) the PID servo period, 5 to 255 msec.
		:LIMit {<limlo> <limhi>}		(?)	Set servo DAC output low limit <limlo> and high limit <limhi>, 0 to 10.0 V
		:I1I2LOW {<curr>}		(?)	(-S1 option only) Set (query) the sum of the two input currents <curr> amps below which the servo will be suspended
		:KP {<prop>}		(?)	(-S1 option only) Set (query) the servo proportional term <prop>
		:KI {<int>}		(?)	(-S1 option only) Set (query) the servo integral term

					<int>
		:PROFile	:LIMit {<prflo> <prfhi>}	(?)	(-S1 option only) Set (query) the DAC start <prflo> and end <prfhi> points for the automatic profile sweep, 0 to 10.0 V
			:POINts	(?)	(-S1 option only) Set (query) the number of data points for the automatic pr0file, (10 to 1000).
		:REFerence {<ref>}		(?)	(-S1 option only) Set (query) the normalizing reference <ref> for the current readings fed to the servo algorithm. Float 32. Typically the stored current in a beam storage ring.
CONFigure?					Query the last configure command
DATa	:CLEar				Clear all data from I200
	:COUnt?				(not supported)
	:FEEd {<source>}			(?)	Set (query) source data feed mask, "11" = data from channels 1, 2
	:POINts {<points>}			(?)	Set (query) the data buffer size (limited to available data memory)
	:VALue? {<index>}				Read data from buffer at index. Returns <integration time, charge1, charge2, over range byte>
FETCh	:CHARge?				Fetch charge data <integration period, charge1, charge2, over range byte>
	:CURRent?				Fetch current data <integration period, charge1, charge2, over range byte>
	DIGital?				Fetch digitals bit0 = digital in 1 bit1 = digital in 2 bit2 (reserved) bit3 = HV enabled bit4 = external gate present
	:PID?				(-S1 option only) Fetch the running servo data .3f DAC starting V .3f DAC present V

					.3f Monitor ADC V .4e Measured process value f(I1,I2) .4e Target process value f(I1,I2) .4e Sum of (TargetProcessValue-ActualProcessValue) .4e Following error (TargetProcessValue-ActualProcessValue) d Error state: 0x01 if DAC limit hit, 0x02 if data invalid or current low limit hit
	:PROFile?				(-S1 option only) Fetch the next profile data point (if not available DataNotAvailable error is returned) .4e Measured process value f(I1,I2) .4f Monitor ADC voltage
FETCh?					Do same FETCh command as previous (defaults to charge if no previous)
INITiate					Initiate readings on valid trigger
PERiod {<period>} [{sub}]				(?)	Set (query) integration period <period> in seconds, 1e-4 to 6.5e1, <sub> subsamples (default is 1)
PID	:SERVo {0|1}			(?)	(-S1 option only) Set (query) servo state 0 = disable 1 = enable
	:PROFile {0|1}			(?)	(-S1 option only) Set (query) automatic profile state 0 = disable 1 = enable The profile will remain ON until either turned off by this command, or when all data points have been read and the profile is completed.
READ	CHARge?				Read charge data. Returns <integration time, charge1, charge2, over range flags>
	CURRent?				Read current data. Returns <integration time, current1, current2, over range flags>
	DIGital?				Read digitals bit0 = digital in 1 bit1 = digital in 2

					bit2 (reserved) bit3 = HV enabled bit4 = external gate present
	:PID?				(-S1 option only) Read the running servo data .3f DAC starting V .3f DAC present V .3f Monitor ADC V .4e Measured process value f(I1,I2) .4e Target process value f(I1,I2) .4e Sum of (TargetProcessValue-ActualProcessValue) .4e Following error (TargetProcessValue-ActualProcessValue) d Error state: 0x01 if DAC limit hit, 0x02 if data invalid or current low limit hit
	:PROFile?				(-S1 option only) Read the next profile data point (if not available, then DataNotAvailable error is returned) .4e Measured process value f(I1,I2) .4f Monitor ADC voltage
READ?					Do same READ command as previous (defaults to charge if no previous)
STATus	:OPERation	:CONDition?			Query operation register status condition bit
		:ENABle		(?)	Set (query) operation register status enable bit
		:EVENt?			Query operation register status event bit
	:QUEStionable	:CONDition?			Query questionable register status condition bit
		:ENABle			Set (query) questionable register status enable bit
		:EVENt?			Query questionable register status event bit
SYSTem	:COMMunication	:CHECKsum {0|1}			Set appending checksum to all replies (password protected) 0 = off 1 = on
		:IDENTIFY?			Sends chained identify command. Devices in the loop combine to assemble the response <number of devices

					in loop, addr of first device, addr of second device, …. addr of last device>
		:TERMinal {0|1}		(?)	Set (query) terminal mode (password protected) 0 = terminal mode off 1 = terminal mode on In terminal mode, ACK and NACK are not sent, and "OK" or error response is sent for all valid commands that do not otherwise generate a response.
		:TIMEout {<timeout>}		(?)	Set (query) timeout in seconds (password protected); 0 = timeout disabled. I200 will go to unconnected state if no valid message is received in the timeout period.
	:ERRor?				Query the next error in the error event queue.
	:FREQUENCY {<Hz>}				Set the dominant noise frequency <Hz> to be suppressed in the calibration routine. This will generally be the line frequency (50 or 60).
	:PASSword {<pass>}			(?)	Set (query) the administrator password <pass> to allow access to protected functions. The default is <12345>.
	:SAFEstate {0|1}			(?)	Set (query) whether the I200 goes to the safe state when unconnected. 0 = do not go to safe state 1 = go to safe state Safe state is HV off.
	:SERIALnumber {<serial>}			(?)	Set (query) the serial number <serial> of the I200, max 10 alphanumeric characters. Password protected.
	:VERSion?			(?)	Query the SCPI standard version
TRIGger	:COUNt?				Query the trigger count since the last INITiate
	:DELAY {<delay>}			(?)	Set (query) the trigger delay for message trigger mode. This parameter permits all devices on a loop to start an acquisition at the same time, despite message propagation delays around the loop.
	:POINts {<poin>|INFinite}			(?)	Set (query) the number of trigger points after an INITiate before acquisition

	:SOURce {<source>}			(?)	Set (query) the trigger source to <source>. The options are: <internal> <external_start> <external_gated> <message> <external_start_stop>
VOLTage {<DAC seting>}				(?)	Set (query) the DAC output used for the servo to <DAC setting> volts, 0.0 to 10.0, float.

20.3 ASCII Protocol – Terminal Mode

SCPI is not ideal for a user trying to control the I200 from a terminal program. A more interactive terminal mode can be turned on by sending the command

SYSTem:COMMunication:TERMinal 1

After this command is executed, the I200 will provide a response to every command. Valid query commands will get their normal reply. Other commands will generate an <OK> response if they were interpreted without errors, or an error message if they could not be interpreted. The non-printing ACK and BEL characters are not sent.

The I200 starts in terminal mode.

20.4 Binary protocol

The binary protocol is optimized for deterministic loop operation, and is primarily intended for use with Pyramid Technical Consultants host software and software device drivers. If you wish to develop your own host software using binary communications, you should contact Pyramid Technical Consultants to discuss available device drivers and wrappers to suit your host environment.

The device model for the binary communications is essentially the same as for ASCII, and particularly the terminal mode. All host messages get an immediate response from the I200. There are a range of summary level commands that are unavailable under SCPI. For example the complete contents of the data buffer can be returned with a single command.

21 Techniques for Making Low Current Measurements

Measurements of currents of around 10 nA and below require some care to prevent unwanted interference that can distort the results. In particular, the conductor that carries the current to the I200 input (the sensitive node) must be carefully isolated and guarded to ensure unwanted currents cannot flow into it.

When an unexpectedly high background offset current is seen, the first thing to do is to check again with the signal input(s) disconnected from the I200. This will isolate the problem to the external measurement circuit, or within the I200 itself.

21.1 Guarding and screening

If the sensitive node is separated from a voltage source (such as a power rail) by an insulating layer, then a small current will flow through the finite impedance of the insulator.

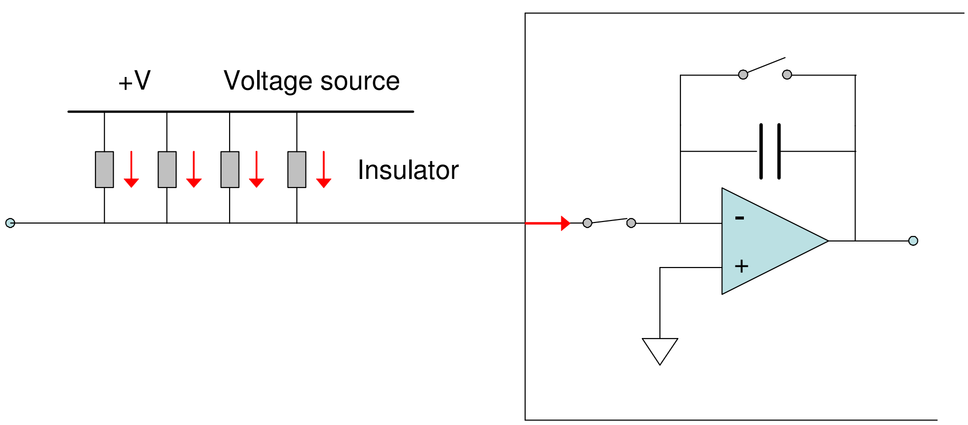


Figure 46. Offset current to unguarded input

For example, a 10 V conductor separated from the sensitive node by 1 Gohm of total resistance would drive in 10 pA of background current. If the insulation is compromised by contamination, then the problem is magnified. The solution is to provide a guard shield around the sensitive node, at the same electrical potential, in a triaxial configuration. Leakages currents across insulators now flow to the guard, where they do not affect the reading.

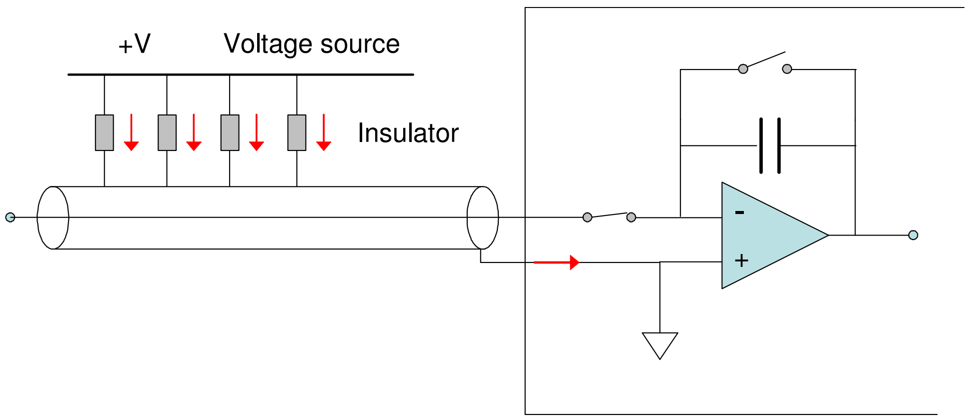


Figure 47. Guarded input

AC fields in the environment can induce AC currents in the sensitive node. Depending upon the frequencies and the integration time in use, these may appear as noise fluctuation in the signal. An outer cable screen is used to shield the sensitive node from external fields. In combination with the need to guard the sensitive node, the result is that the use of triaxial cable is necessary in this case.

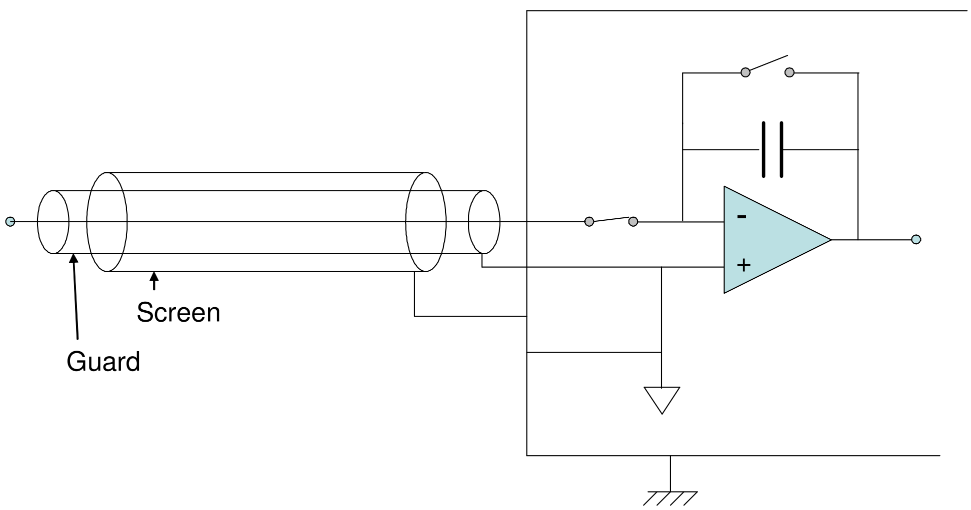


Figure 48. Guarded and screened input

Practical measurements have shown that triaxial cable is rarely needed for the I200. This is in contrast to the Pyramid I400 device, where it is essential because the signal inputs can be biased several hundred volts from ground. It is more important to minimize triboelectric noise (see below).

21.2 Temperature

Offset factors are generally exacerbated by increased temperatures. Temperature fluctuation can appear as variation in the reading. When very small currents need to be measured, the experimental arrangement should be temperature stabilized as far as possible.

21.3 Triboelectric effects

When there is relative movement of insulators and conductors in signal cabling, free charge is released. This is particularly the case for the screen of coaxial cable. The resulting potential difference can drive small currents to the signal conductor across the high impedance of the insulator. Additionally, charge may leak in directly if there are any breaks in the insulator.

Special low-noise cable is available with graphite lubrication bonded to the insulator, to reduce charge generation, and to conduct any released charge away harmlessly. Belden 9010-010100 low-noise RG-58 coax cable has been tested and found to be satisfactory. Figure 49 shows triboelectric noise in amps caused by deliberate flexing of coaxial cable for about ten seconds, such as might occur in a motion actuator system. Noise of about +/-1 nA was seen with standard RG-58, but this was reduced to about +/- 25 pA with low-noise RG-58.

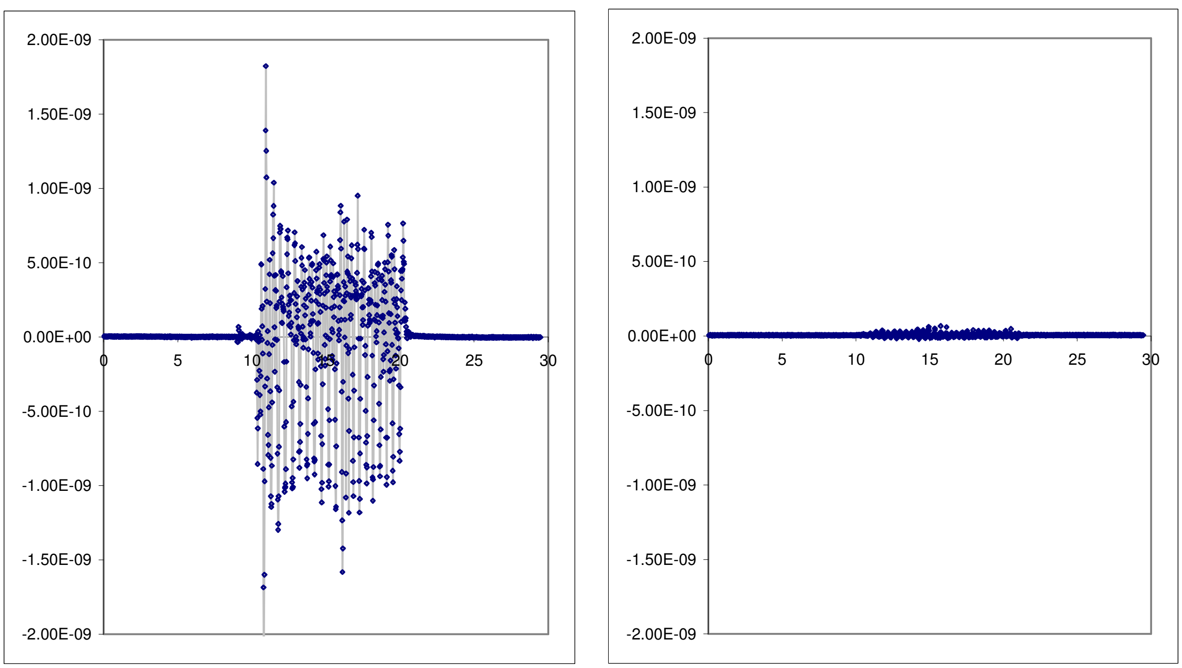


Figure 49. Comparison of triboelectric noise caused by flexing standard RG-58 (left) and low-noise RG-58 (right)

Other mitigations include keeping the signal cables short and motionless.

21.4 Battery Effects

Ionic contamination, such as salt from fingerprints, which connects to the sensitive node, can give battery effects, particularly in the presence of moisture, which can drive unwanted currents. Any insulating surfaces in contact with the sensitive node must be clean. Humidity levels should

be such that there is no moisture condensation. Wherever possible the sensitive node should be insulated by vacuum or air.

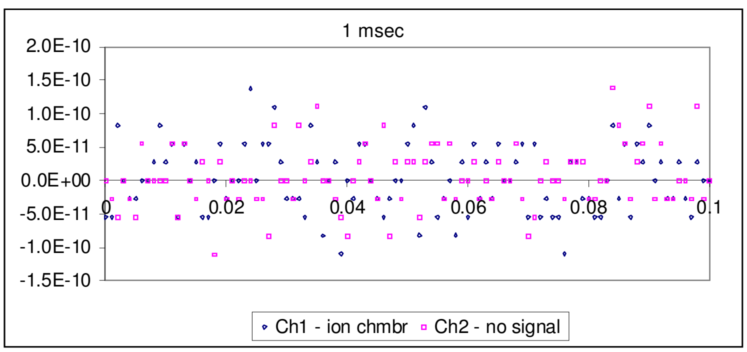
21.5 Piezoelectric Effects

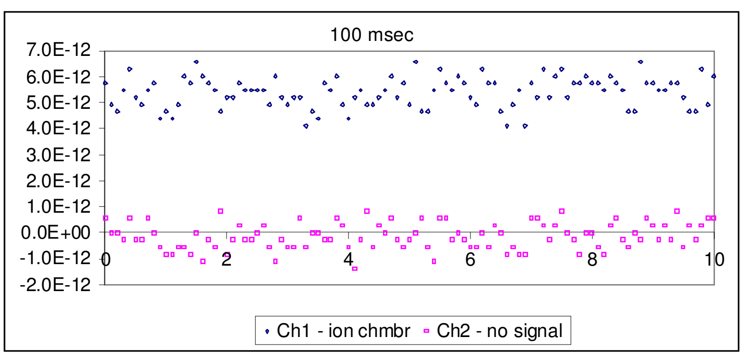
Ceramic and plastic insulators can release charge when under mechanical stress, which may be collected on the sensitive node. The effect is generally small (less than 10 pA), and can be avoided by eliminating stresses in cables and connections.

21.6 Integration Period and Synchronization

The I200 provides considerable flexibility in setting the integration time interval, and synchronizing the integration to external events. The integration method is inherently good at averaging noise. Very low current currents generally require the smallest available feedback capacitor and the longest practicable integration time to build up a readily measurable voltage. For example, a 1 pA current integration on a 10 pF feedback capacitor requires 10 seconds to develop 1 V. Background offset noise is also integrated, of course, and cannot be distinguished from the signal. This sets the ultimate detection limit.

The plots in figure 44 illustrate how a 5 pA signal from a small ionization chamber becomes clearly distinguishable from a reference background signal, and the noise reduces, as the integration period is increased from 1 msec to 100 msec to 10,000 msec.





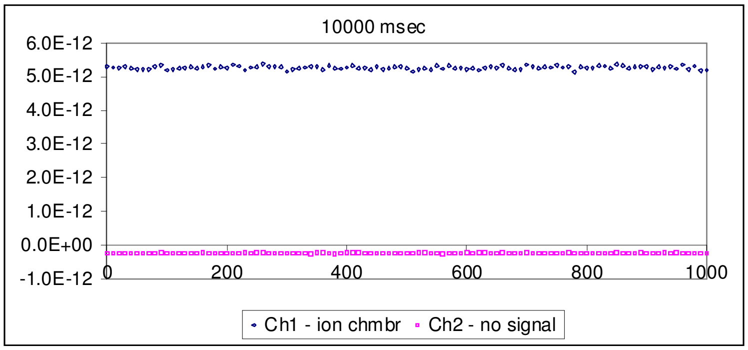


Figure 50. Separation of a 5 pA signal from background, integration periods 1 msec, 0.1 sec and 10 sec.

Where there are known dominant noise frequencies in current measurements, for example line voltage interference, these can be suppressed by choosing an integration periods that is an integer multiple of the noise period. For example, 50 Hz or 60 Hz noise from the power line is present in most environments. This can be completely removed in the I200 by selecting the integration period as follows:

Noise frequency	**Integration period choices to eliminate noise**
50 Hz	20.00, 40.00, 60.00, 80.00, 100.00 …. K x 20.00 msec
60 Hz	16.67, 33.33, 50.00, 66.67, 83.33, 100.00, …. K x 16.67 msec

Note that 100 msec is a useful integration time because it suppresses both 50 Hz and 60 Hz noise. Very small charge package measurements should be optimized by synchronizing the integration carefully around the arrival of the charge. This minimizes the amount of background offset current that is included in the reading. Often the arrival of the charge is associated with an event in the system which can be used to drive the external gate input of the I200 to obtain the required synchronization.

21.7 Summary

Factor	**Typical noise offset current**	**Mitigation**	**Typical noise after mitigation**
Triboelectric effects in cable	10^{-8} A	Reduce cable lengths. Keep cable from moving. Use low-noise cable.	10^{-12} A
Current across insulators from voltage	10^{-7} to 10^{-10} A	Guard the sensitive node Use triaxial cable	10^{-12} A

sources			
AC interference	10^{-6} to 10^{-10} A (AC)	Used screened (coaxial or triaxial) cable	10^{-12} A
AC interference	10^{-6} to 10^{-10} A (AC)	Use integration periods that are an integer multiple of the dominant noise frequency.	10^{-12} A
Contaminated insulators	10^{-8} A	Clean insulating surfaces with solvent Use air insulation where possible Keep humidity low	10^{-13} A
Piezoelectric effects	10^{-12} to 10^{-13} A	Avoid mechanical stresses and vibration, in the sensor and cable.	Negligible
Resistor Johnson noise	$< 10^{-14}$ A	None – fundamental limit set by signal source resistance	
Temperature fluctuation	10^{-9} to 10^{-12} A fluctuation	Temperature stabilize the whole measurement apparatus	10^{-10} to 10^{-14} A fluctuation
Elevated temperature	10^{-13} to 10^{-11} A	Reduce temperature of the whole measurement apparatus	10^{-13} A

22 Servo Control Applications

The I200 with the -S1 option contains additional hardware and software to allow it to control any process that can be commanded by a 0 to 10 V analog output signal, and which can be monitored through one or two small current signals. The I200-S1 calculates a process variable which is one of five available arithmetic combinations of the two input signals. The servo algorithm adjusts the analog output voltage in order to maintain a selected value of the process variable.

Although the I200 can in principle stabilize any system that meets these criteria, these notes will focus on the X-ray Double Crystal Monochromator intensity stabilization application. The –S1 option was developed initially with this application in mind.

22.1 DCM stabilization

A Double Crystal Monochromator (DCM) accepts a broad frequency spectrum of X-radiation from a source such as a bending magnet or insertion device in an electron storage ring, and produces a nearly monochromatic output beam by Bragg diffraction from two crystals mounted on a crystal cage. The Bragg angle and thus wavelength is selected by a precision rotary bearing. Fine adjustment is achieved by a micro-motor system such as a piezo motor drive. The X-ray beam intensity can be sensed by devices such as ionization chambers or photodiodes located downstream and upstream of the DCM.

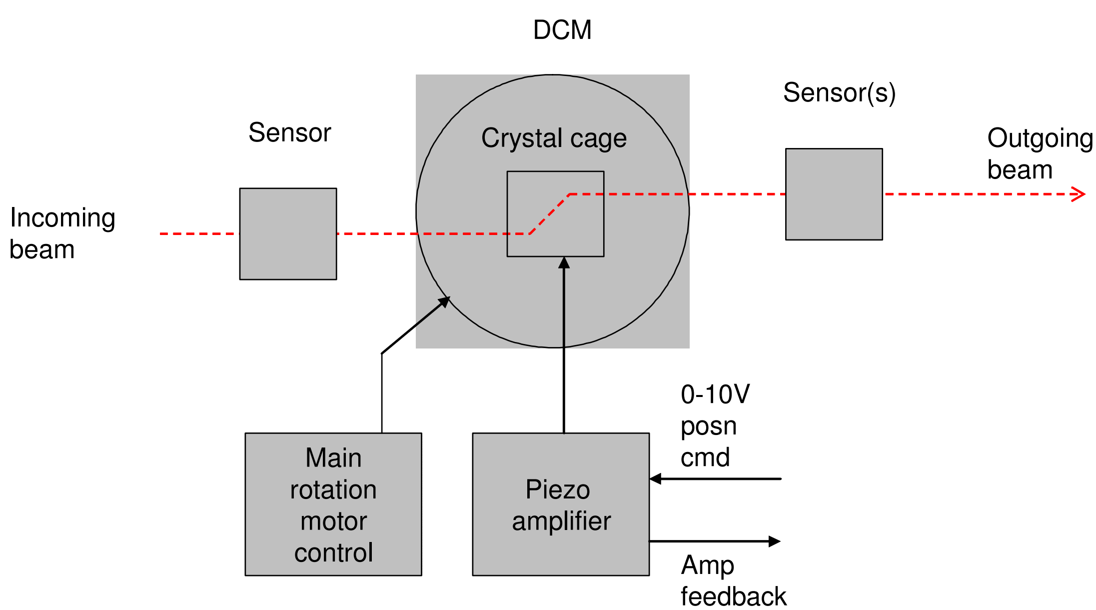


Figure 51. DCM components relevant to servo stabilization

Under operating conditions the operating point, the output beam intensity variation as a function of the piezo position command forms a well-defined peak. Many X-ray experiments require that the beam intensity after the monochromator is stable, despite small fluctuations in the monochromator setting or the primary beam. This can be achieved by monitoring the output beam and adjusting the piezo drive to maintain intensity under servo control.

In the simplest sensor system, a single beam intensity sensor such as an ionization chamber or photodiode senses the beam intensity downstream of the monochromator. In this simplest case, the process variable is simply the current reading from channel A, called I1 in the PSI Diagnostic software. The I200 is perfectly suited to read out an ionization chamber, and can also provide high voltage to the chamber if needed. The I200–S1 option provides a high-resolution analog output to program the piezo motor amplifier, and an auxiliary analog input to read the motor position feedback.

The integrated I200 profile function allows you to program a sweep of the analog output DAC between defined limits, and with a defined number of steps, N_{steps}. A current integration is made at each step, so the duration of the sweep is given by t_{per} x N_{steps}. Clearly it can be best to start with a coarse profile, using full span, fewer steps and/or shorter integration, before refining the range, number of steps and integration time to get a good measurement of the output beam intensity as a function of the DAC output voltage.

Assuming the DCM is positioned so that the required peak is within the piezo range, the response will show a well-defined peak. A simulated example is shown in figure 52.

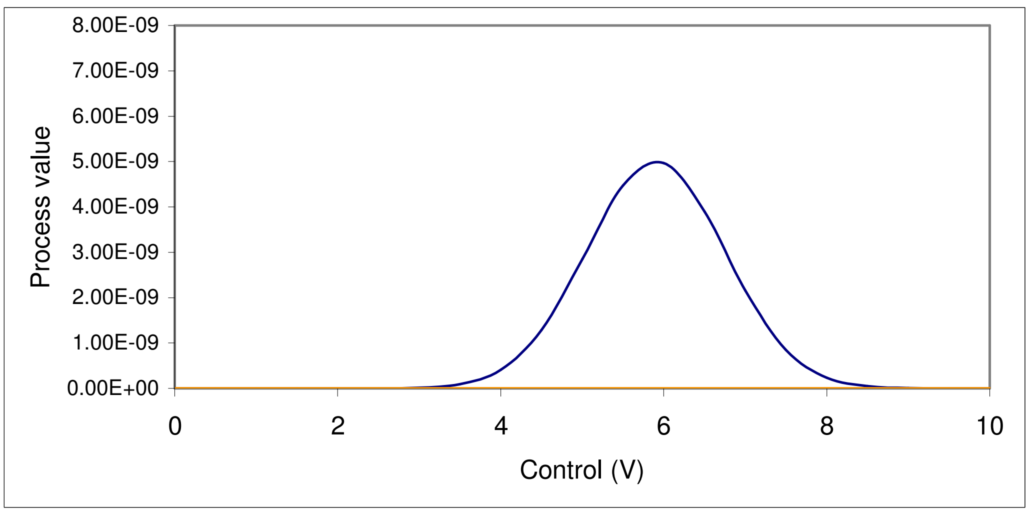


Figure 52. Simulated system response function

The general experimental requirement is for a stable and high beam flux. If an operating point is defined on the side of the peak, towards the top, then a good compromise can be achieved where there is scope for the servo to move up or down the peak to stabilize the current, but not too much flux has been given up relative to the peak. Move the DAC to the required operating point by direct command, and note that the expected current is being measured. This current value (the process variable value) is the one that will become the servo target once the servo is enabled.

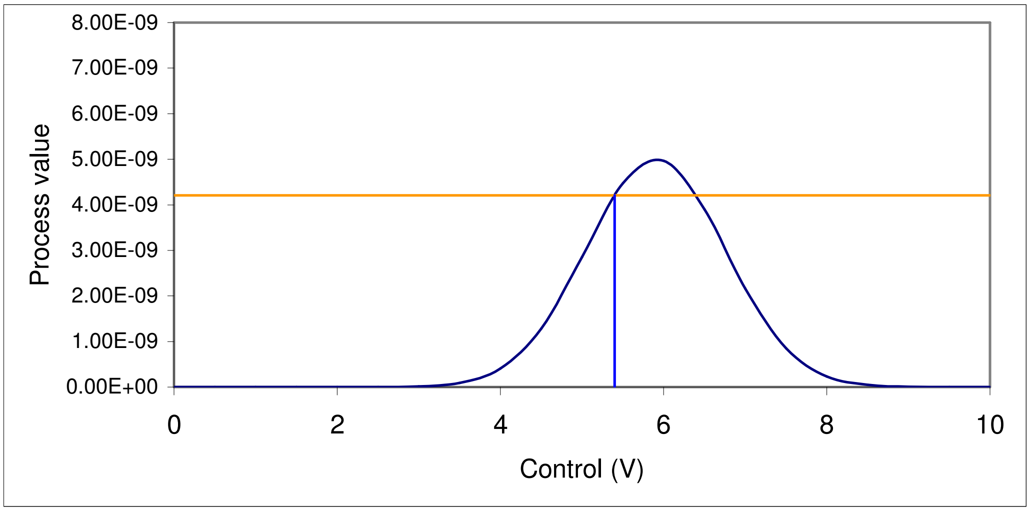


Figure 53. Example operating point selection. Blue – user-selected DAC setting; orange – corresponding measured current that will be used as the servo target

In order to reduce the risk that the servo looses control if there are extreme perturbations, you can set low and high excursion limits on the DAC output.

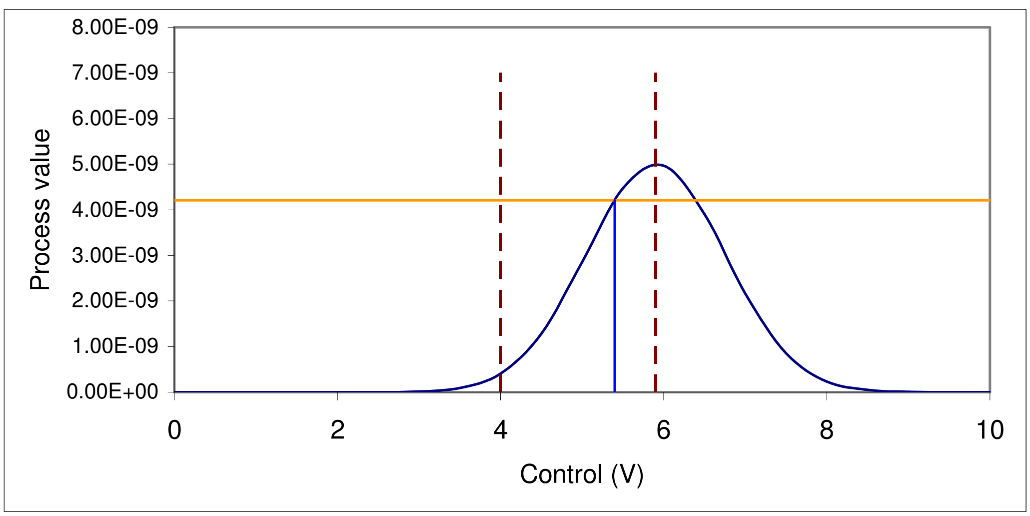


Figure 54. Limits set on control parameter (DAC voltage)

22.2 Process parameter options

The I200-S1 allows selection of five possible process parameters that will be stabilized by the servo. The options are various arithmetic combinations of the two input signals, I1 and I2.

1	I1
2	I1 + I2
3	I1 – I2
4	I1 / I2

5	(I1 – I2) / (I1 + I2)

Modes 1 and 2 are typical for detector systems on the output side of a DCM. Mode 4 allows the output flux from a DCM to be normalized to the input flux, so that the servo will not respond to variations in the beam, but only to variations introduced by the DCM. Mode 5 allows stabilization on the signal from a one-dimensional position sensor such as a split electrode ion chamber.

22.3 Process parameter normalization

Some servo applications may work best if you make the servo insensitive to a particular external effect. For example, you may require the servo to respond to mechanical drift in the DCM or other beamline components, but not to the slow drop in the circulating current in the storage ring. In modes 1,2 and 3, the servo would attempt to compensate the resulting drop in flux, and would probably run out of control range at some stage.

The I200-S1 allows this external parameter, P, to be removed from the servo response by normalizing the two current readings before they are passed to the calculation.

I1 becomes I1/P

I2 becomes I2/P

Thus if the measured currents on the I200 inputs are directly proportional to P, any change due to variation in P is cancelled. The I200-S1 cannot measure P directly, but you can pass it a value that has been measured by other means via the communication link. This can be done at any time, including while the servo is running. In between updates to the value of P, the servo will be responding to its effect on the readings, but by using a suitable rate of updates, you can remove effect of its longer term drift.

Note that the value of P is irrelevant in servo modes 4 and 5, as it simply cancels out.

Process parameter normalization is included in firmware release 4.0E and later.

22.4 Servo algorithm

The I200 implements a PI (proportional / integral) servo in firmware. New values for the control voltage (DAC output) are given by

$$DAC_{out} = DAC_{initial} + k_{\mathrm{Pr}op}.err + k_{Integral}.\sum err$$

where err is the difference between the target process value, measured at the time the servo was enabled, and the latest measured value. k_{Prop} and k_{Integral} are the servo terms. DAC_{initial} is the starting DAC value that the I200 was putting out when the servo was enabled. The sum term keeps a running total of the errors since the servo was enabled.

The update period for the servo calculation is user-definable, in the range 5 msec (200 Hz) to 255 msec (3.92 Hz). Note that this period is not linked to the integration frequency. According to how you set these two parameters, there may be a new process value for every servo iteration, many more process values than are used, or multiple use of the same process value.

The err value either has units of current or charge (modes 1, 2, 3), or is dimensionless (modes 4, 5). If you are using process parameter normalization, and the units of P are also convolved. In order to keep the magnitude of the servo terms similar, the values that the user enters are normalized to the full-scale current for modes 1, 2, 3. Actual values will depend greatly upon the application, but should be in the range 0 to about 100.

If the DAC_{out} value reaches the lower or upper user defined by the user, the servo calculation is suspended except in that any err values that would tend to move the control value off the limit are added to the sum. This allows the servo to move back from the limit automatically if the error terms permit.

If the user-defined low limit for I1 + I2 is reached, or if either of the inputs goes overrange, the servo is suspended. The I200 continues to put out the last output until the current(s) recover over the low limit.

22.5 Servo tuning

If you are holding a position on the left hand side of a positive peak in the mode 1 process parameter case, as shown in figure 53, then the servo parameters need to be positive. This is because a positive error (meaning the actual process value is below the target) requires an increase in control value to move up the side of the peak. Conversely, stabilizing on the right hand side of the peak will require negative values. Generally, the servo parameters will be positive if the process response curve has positive slope in the region you wish to stabilize in, and vice versa.

Be careful to set the low and high servo limits correctly. If they are too tight, then the servo will not be able to follow the full range of perturbations. If they are too wide, the servo may “fall off” the peak, or move over the top of the peak.

If the response of the system to control inputs has negligible lag, then you may find that only integral control is necessary. If there is lag, then adding proportional term will improve the response time. Too much of either term will make the loop unstable, and the control output will start to oscillate. The following simulated example shows how tuning the loop might proceed.

Initially with both servo terms set to zero, the system is unresponsive to changes in the process value.

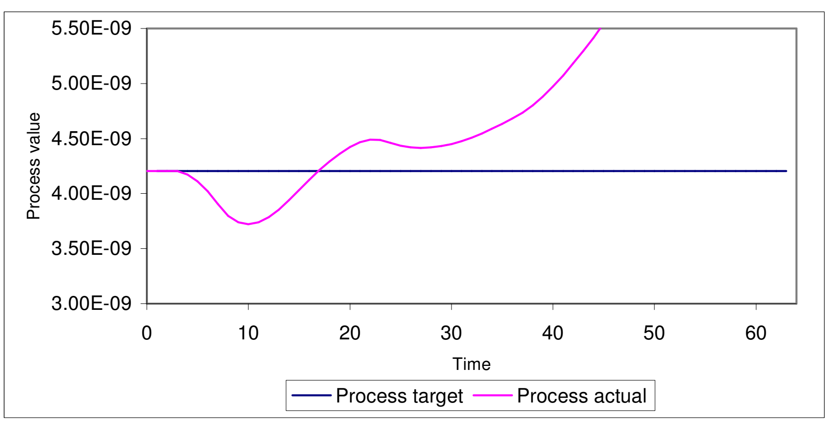


Figure 55. Example system response with no servo.

If we now introduce some integral term, the system starts to respond to the perturbations.

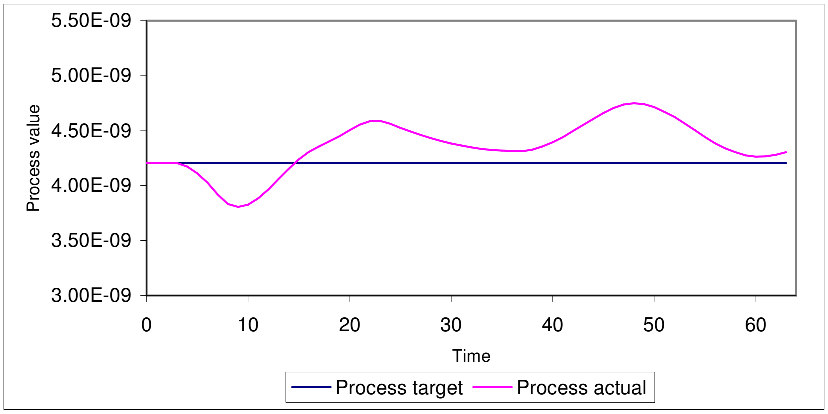


Figure 56. System response with integral servo term.

Increasing the integral term leads to some oscillation due to phase lag in the system.

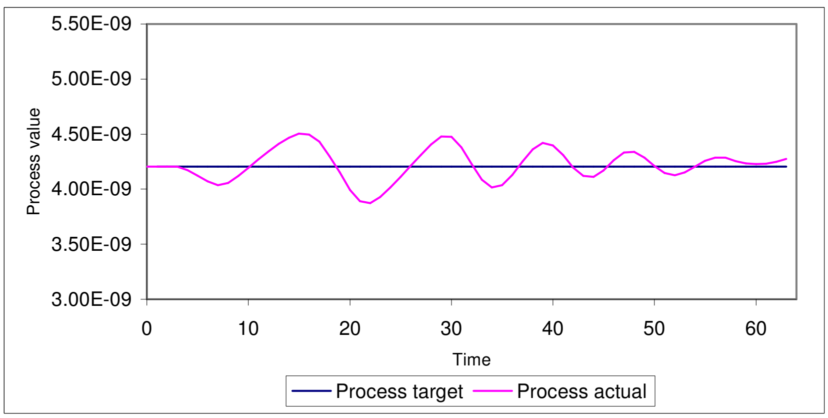


Figure 57. System response with excessive integral servo term.

Adding some proportional term damps the oscillation.

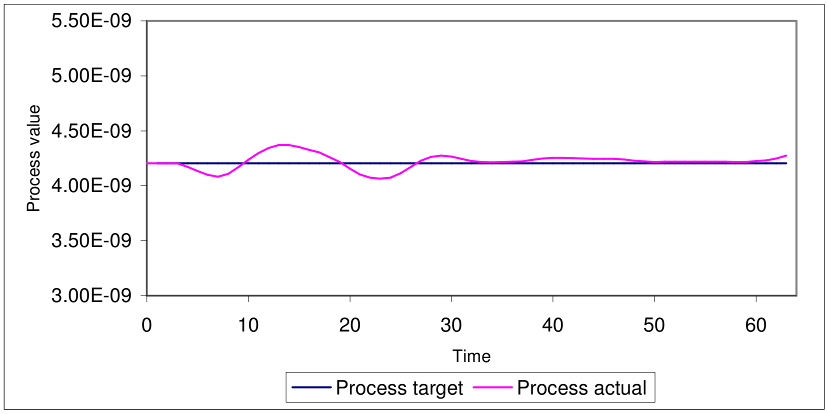


Figure 58. System response with integral and proportional servo terms.

Both terms can now be increased in steps until a tendency for instability becomes evident.

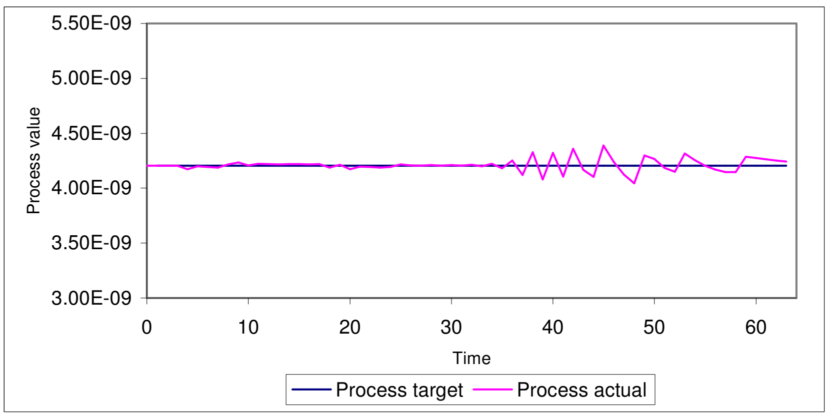


Figure 59. System response at stability limit.

You should then back off the settings until any tendency for instability is eliminated.

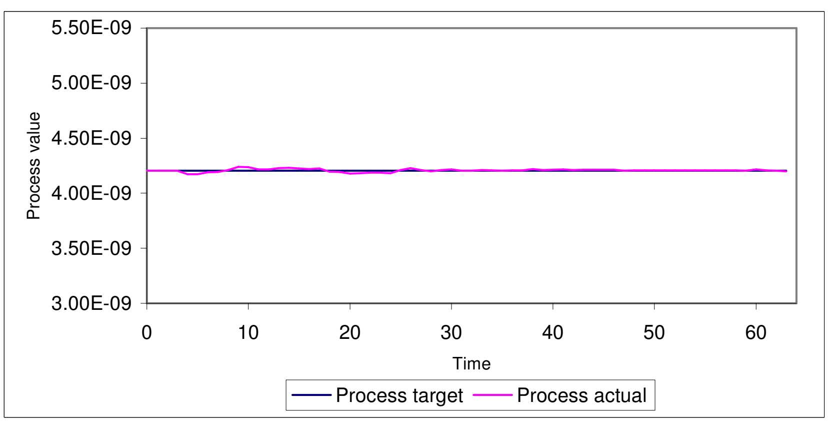


Figure 60. System response with optimized integral and proportional terms.

23 The -100AB Option

The I200-100AB is a special order option of the I200 which allows you to have a factor of 100 difference in sensitivity between input channels A and B. This can be useful particularly in servo applications that involve a ratio of the two signals (servo mode 4). As an example, a double crystal monochromator application can involve one sensor monitoring at the input beam and another looking at the monochromated beam which can be hundreds of times lower intensity. In order to optimize the signal to noise ratio and resolution with this large intensity ratio, it can be compensated with a corresponding sensitivity ratio between the two I200 input channels. An I200 with both servo options and the -100AB option is designated I200-S1-100AB.

A special hardware modification in the -100AB version provides this feature. The feedback capacitor selection is altered to be as follows:

Capacitor selection	*Input A*	*Input B*
Small “10 pF”	10 pF	10 pF
Large “1000 pF”	10 pF	1000 pF

Note that the unit operates normally when the small capacitor is selected. When the large capacitor is selected, however, only channel B changes to the larger capacitor. The result is that channel A now has one hundred times higher sensitivity, and correspondingly lower full scale current, than channel B for any setting of integration time.

The I200 firmware needs to be aware that the hardware operates this way. Any version of FPGA code 9.1.11 or later and PIC device code 4.0C or later can support the -100AB option. A jumper setting on the I200 circuit board enables the correct firmware features. Jumpers are fitted on positions 5 and 6.

CAUTION

Do not set these jumpers for standard I200 units, or you will get incorrect readings.

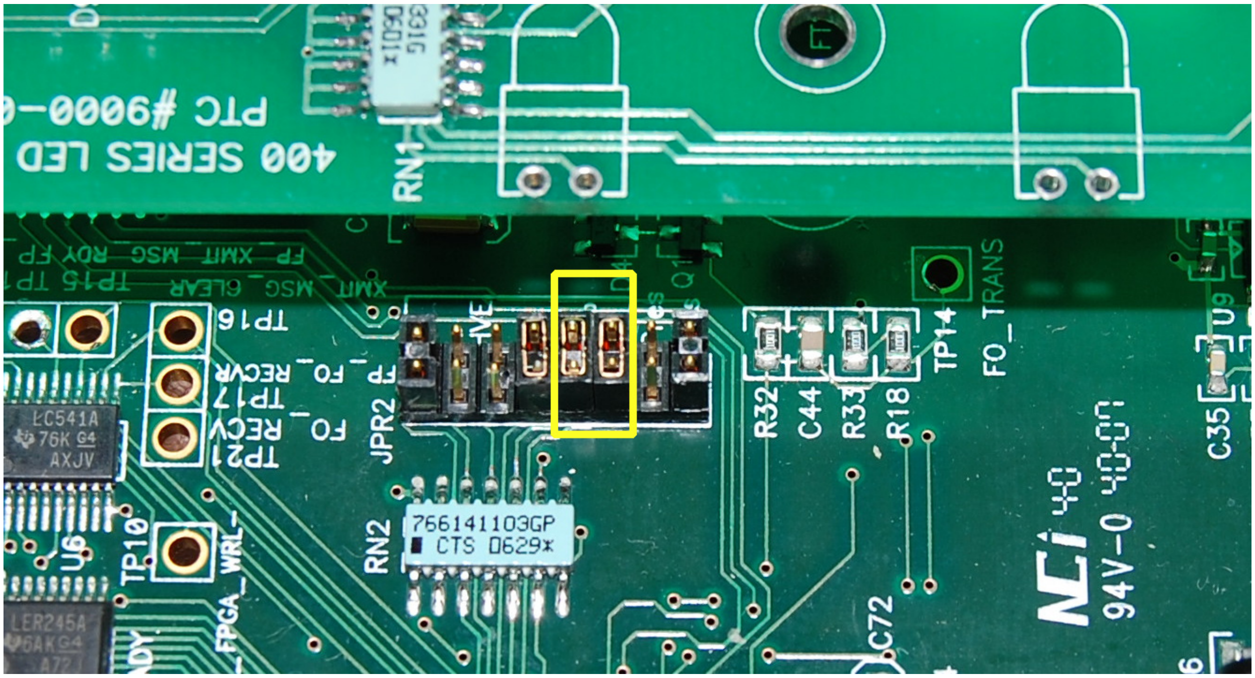


Figure 61. Internal jumper setting for the -100AB option.

24 Fault-finding

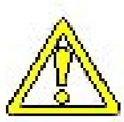
Symptom	Possible Cause	Confirmation	Solution
High background current	Resistive path to signal input due to missing or broken guard.	Disconnect input – background should reduce to specification levels	Ensure good guard integrity all the way to the signal source.
	High humidity	Problem varies with relative humidity.	Ensure there are no water-absorbent insulators. Reduce the humidity levels.
	Internal contamination.	Background current remains high with inputs disconnected.	Contact your I200 supplier for advice or to organize a return for cleaning.
High noise levels	Integration time too short for signal being measured	Noise level reduces with integration period	Use an appropriate integration time for the signal level.
	RF pickup	Noise varies with cable position, status of neighboring equipment.	Check integrity of outer screens of signal cables.
	Line voltage pickup	Noise level drops sharply if integration period is 16.7 msec (60 Hz) or 20 msec (50 Hz)	Keep I200 and signal cables clear of unscreened high current mains voltage. Use integration periods (N/line frequency).
No signal	Small signal lost in noise	Signal appears as integration period is increased.	Use longer integration time.

Signal does not vary as expected	Integrators are overrange.	Overrange flags are set, signal recovers if integration period is reduced.	Reduce the integration period or use the larger feedback capacitor.
Measured currents or charges are inaccurate by up to 15%	Unit not calibrated.		Calibrate.
	Calibration was carried out while a signal current was present.	Internal calibration source does not measure as 500nA with all inputs disconnected.	Repeat calibration with no external signal present.
High background offset current	Various causes		Refer to section 21.
500 nA background on all channels.	Internal calibration source has been turned on.		Turn off calibration source.
I200 stops measuring	Trigger points limit reached.	Measurement starts again if I200 is reinitialized.	Adjust trigger points as required.
	Data buffer full.	Measurement starts again if I200 is reinitialized.	Adjust data points as required and/or turn on data buffer wrap.
	Communication link timeout		Investigate and fix communications issue. Use a longer timeout setting.
No or incorrect response to external trigger or gate	Incorrect gate polarity selected.		Use correct polarity.
	I200 not configured to respond to external gate.		Use correct setup.
No high voltage	Shorted to ground in external	Monitor HV reading zero or	Eliminate shorts to ground.

	circuit	very low relative to setpoint. Monitor value recovers if I200 disconnected from the external circuit.	
Cannot set high voltage	Trying to set above the maximum allowed value soft limit.	Sets OK if a lower value is chosen.	If allowed, increase the maximum allowed value.
Unable to communicate with I200	Wrong mode switch or address setting	Check mode switch setting against table in section 16 and address against expected address in host software.	Use correct switch settings. Switches can be changed while the unit is operating.
Unable to connect on fiber loop	Connector still fitted to RS232 or USB		Remove RS232 and USB connectors.
Communications interruptions	Other processes on PC host interfering with comms ports.		Use a dedicated PC with simple configuration and minimum number of processes running.
Unable to connect on USB	Missing or incorrect USB driver.	Device connected tone not heard when connecting the USB cable.	Install correct driver. Refer to the I200 Software Manual.
Unable to connect on RS232	Another program is using the COM port.	Try to access the required port with Windows Hyperterminal.	Choose another port or close down the other program.
	Incorrect port settings.	Try to connect with the .htm file supplied with the unit.	Correct the settings.
	Incorrect cable.		Make up a suitable cable. See figure 5.

25 Maintenance

The I200 does not require routine maintenance. There is risk of contamination which may degrade performance if the case is opened. There are no user-serviceable parts inside.



CAUTION. High voltages are present inside the case. Do not open the case when power is applied.

The I200 is fitted with a 1.1 A automatically resetting positive temperature coefficient (PTC) fuse in the 24 VDC input. No user intervention is required if the fuse operates due to overcurrent. The fuse will reset when the overcurrent condition ends.

26 Returns procedure

Damaged or faulty units cannot be returned unless a Returns Material Authorization (RMA) number has been issued by Pyramid Technical Consultants, Inc. If you need to return a unit, contact Pyramid Technical Consultants at support@ptcusa.com, stating

- model
- serial number
- nature of fault

An RMA will be issued, including details of which service center to return the unit to.

27 Support

Manual and software driver updates are available for download from the Pyramid Technical Consultants website at **www.ptcusa.com**. Technical support is available by email from support@ptcusa.com. Please provide the model number and serial number of your unit, plus relevant details of your application.

28 Disposal

We hope that the I200 gives you long and reliable service. The I200 is manufactured to be compliance with the European Union RoHS Directive 2002/95/EC, and as such should not present any health hazard. Nevertheless, when your I200 has reached the end of its working life, you must dispose of it in accordance with local regulations in force. If you are disposing of the product in the European Union, this includes compliance with the Waste Electrical and Electronic Equipment Directive (WEEE) 2002/96/EC. Please contact Pyramid Technical Consultants, Inc. for instructions when you wish to dispose of the device.

29 Declaration of Conformity

Declaration of Conformity

Issued by: Pyramid Technical Consultants, Inc.
1050 Waltham Street, Lexington MA 02421, USA

The undersigned hereby declares, on behalf of Pyramid Technical Consultants, Inc. that the referenced product conforms to the provisions as listed. Refer to the document: *Extension of testing and analysis to the PTC product line, December 10, 2007* and the *I400 Technical Construction File* for detailed testing information.

Product:	I200 Dual Charge Integrator
Year of initial manufacture:	2007
Applicable Directives:	73/23/EEC Low Voltage Directive: Laws for electrical equipment within certain voltage limits 89/336/EEC – EMC Directive: Laws relating to electromagnetic compatibility
Applicable Standards:	IEC 610101:2002 (2^{nd} Edition) UL 61010-1:2004 EN 61326: 1997+A1:1998+A2:2001 EN 55011:1998, A2:2002 EN 61000-6-2:2001 – Electromagnetic Compatibility Generic Standard, Immunity for Industrial Applications
Issuing Agencies:	Safety: TUV Rheinland North America. 12 Commerce Rd, Newtown, CT 06470 USA EMC: TUV Rheinland North America. 12 Commerce Rd, Newtown, CT 06470 USA
Applicable Markings:	TUV, FCC, CE
Authorized by:	R.P. B President, Pyramid Technical Consultants, Inc.
Date:	3-Apr-08

The Technical Construction File required by theses Directives are maintained at the offices of Pyramid Technical Consultants, Inc, 1050 Waltham Street, Lexington MA 02421, USA
A copy of this file is available within the EU at the offices of Pyramid Technical Consultants Europe, Ltd, 2 Chanctonbury View, Henfield BN5 9TW, United Kingdom.

30 Revision History

The release date of a Pyramid Technical Consultants, Inc. user manual can be determined from the document file name, where it is encoded yymmdd. For example, I200_UM_080105 would be an I200 manual released on 5 January 2008.

Version	***Changes***
I200_UM_071205	First general release
I200_UM_080721	Default signal connectors changed from triaxial to coaxial ExternalGate trigger mode removed. CE conformance certificate added.
I200_UM_080821	Descriptions and examples of 20 μsec time resolution added.
I200_UM_100526	Add VOLTage command missed from ASCII list. Add section on disposal
I200_UM_110905	Add Overview section Add description of servo process parameter normalization Add section on -100AB option